Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring.

Horseshoe Lake, Lassen Volcanic National Park

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Overview

Water quality monitoring is being developed as an important, integrated element of the Klamath Network Vital Signs Monitoring Plan. A general understanding of the role of water quality monitoring in the Klamath Network, therefore, can be obtained from the main plan. This appendix is intended to provide additional detail about our plans for monitoring freshwater quality and aquatic communities to ensure that we are in compliance with NPS Water Resource Division guidance and to provide direct support for the implementation of water quality monitoring in the Network. The sections below follow the 11 chapter titles in the Vital Signs Monitoring Plan. Because it is considered supplemental to the main plan, additional detail is only provided for those chapters where it was deemed necessary.

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Chapter 1: Introduction and Background

1.1. Overview of Klamath Network Aquatic Resources

The parks of the Klamath Network (Figure 1) are Crater Lake National Park (hereafter Crater Lake NP), Lassen Volcanic National Park (hereafter Lassen NP), Lava Beds National Monument (hereafter Lava Beds NM), Oregon Caves National Monument (hereafter Oregon Caves NM), Redwood National and State Parks (hereafter Redwood NP), and Whiskeytown National Recreation Area (hereafter Whiskeytown NRA). The parks are located in southern Oregon and northern California in a rugged region with patterns of complex climate, topography, geology, and diverse aquatic resources. The cover figure of Horseshoe Lake in Lassen NP is an example of one type of aquatic resource present in Klamath Network park units and is representative of inland montane lakes within the Network. Crater Lake NP (74,140 ha; 182,304 ac) is responsible for managing the clearest and seventh deepest (592 m, 1942 ft) caldera lake in the world. In addition, Crater Lake NP contains deep lake thermal areas, small ponds outside of the Mt. Mazama caldera, numerous streams and springs, and several important wetland areas. Lassen NP (43,047 ha; 106,372 ac) includes the largest concentration of freshwater lentic systems in the Network, with over 250 ponds and lakes (many of which have never been inventoried). The park also has several major stream drainages, geothermal areas, and sphagnum bogs along lake margins. Lava Beds NM (18,842 ha; 46,560 ac) has limited surface water, although Tule Lake and the Tule Lake Wildlife Refuge are present near the northern border of the monument. Lava Beds NM does, however, have approximately 28 known ice caves that are an important source of water for wildlife and, historically, for humans. Oregon Caves NM is a small unit (194 ha; 480 ac). Cave Creek flows through the main cave and wet meadows and seeps are present in the upper canyon of the creek. Parts of Cave Creek are directly affected by visitors touring the cave. Redwood NP (42,701 ha; 105,516 ac) has marine and freshwater aquatic resources. Marine resources include over 62 km (37 mi) of coastal marine habitat extending 0.4 km (0.25 mi) offshore and coastal estuaries and lagoons. Freshwater resources include Redwood and Mill Creeks and their watersheds, and slope fens and seeps. Whiskeytown NRA (17,198 ha; 42,497 ac) contains a large reservoir, Whiskeytown Lake (1296 ha; 3200 ac) created by the damming of Clear Creek, as well as many perennial and intermittent tributary streams. Historically, mining was a common enterprise within Whiskeytown NRA and as a result, acid mine drainage and mercury contamination are of major concern. Whiskeytown NRA also contains the only known global population of Howell's alkali grass (*Puccinellia howellii*), which is restricted to a mesosaline fen in the park. A detailed summary of past inventory, monitoring, and research activities in the Klamath Network park units is available in Appendix F – Water Quality (pages 16-39 and Attachment I) of the Phase II Report, available at http://www1.nature.nps.gov/im/units/klmn/MON_Phase_II.cfm.

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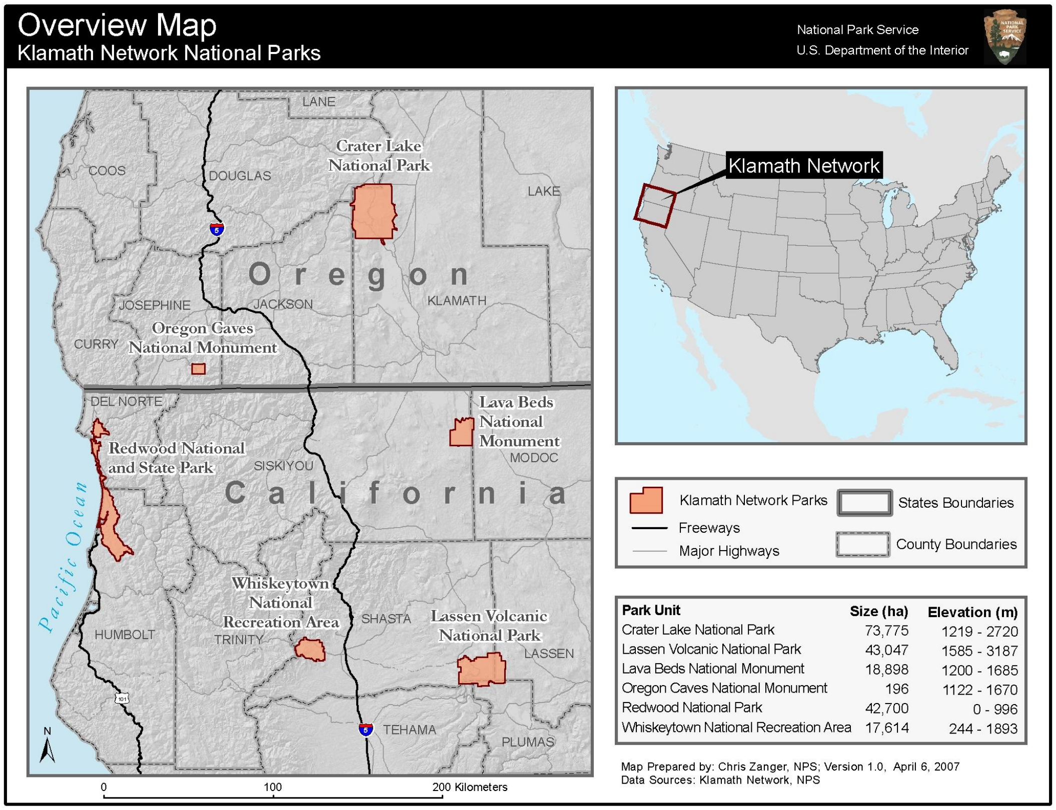

Figure 1. Klamath Network park units: Crater Lake National Park, Lassen Volcanic National Park, Lava Beds National Monument, Oregon Caves National Monument, Redwood National and State Parks, and Whiskeytown National Recreation Area.

National Park Service Water Resources Division Baseline Water Quality Inventory

The baseline water quality inventory is part of a National Park Service Water Resources Division (NPS-WRD) program to develop baseline water quality information for key resources in National Park Service units throughout the United States. Baseline water quality inventories were completed at Lava Beds NM, Lassen NP, and Oregon Caves NM in 2005 (Currens et al. 2006). The following parameters were measured for all water bodies selected for the inventory: alkalinity, dissolved oxygen, pH, specific conductance, temperature, and discharge (where applicable). Additional parameters measured for select water bodies included fecal and total coliform, chloride, fluoride, nitrate and sulfate. Horizon Reports of past baseline water quality data inventory and analysis, available at http://www1.nature.nps.gov/im/units/klmn/MON_Phase_II.cfm, have been completed by the NPS WRD for Lassen NP (NPS-WRD 1999a), Lava Beds NM (NPS-WRD 1999b), Oregon Caves NM (NPS-WRD 1998), and Whiskeytown NRA (NPS-WRD 2000).

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Outstanding Natural Resource Waters

No designated Outstanding Natural Resource Waters (ONRW) occur within the Klamath Network. Crater Lake NP however, is in the process of obtaining ONRW designation for Crater Lake from the Oregon Department of Environmental Quality.

The North Coast Regional Water Quality Control Board has identified Redwood NP as a State Water Quality Protection Area as designated by the California State Water Board. There also are several Redwood NP marine areas designated as Areas of Special Biological Significance by the State of California. The coast off Redwood NP is part of a California Marine Sanctuary, and Redwood NP has a California State Lands Commission Submerged Lands Lease to conduct resource management activities.

Wild and Scenic Rivers in the Klamath Network Region

All of the information contained in this subsection is from the National Wild and Scenic Rivers website: http://www.nps.gov/rivers/wildriverslist.html.

1. Klamath River:
   A. **Designated Reach:** January 19, 1981. From the mouth to 1,097 m (3,600 ft) below Iron Gate Dam. The Salmon River from its confluence with the Klamath to the confluence of the North and South Forks of the Salmon River. The North Fork of the Salmon River from the Salmon River confluence to the southern boundary of the Marble Mountain Wilderness Area. The South Fork of the Salmon River from the Salmon River confluence to the Cecilville Bridge. The Scott River from its confluence with the Klamath to its confluence with Schackleford Creek. All of Wooley Creek.
   B. **Classification/Mileage:** Wild – 19 km (12 mi); Scenic – 39 km (24 mi); Recreational – 403 km (250 mi); Total – 461 km (286 mi).
   C. **Managing Agencies**: California Resources Agency; Yurok Tribe; Hoopa Valley Indian Reservation; Klamath National Forest; Bureau of Land Management.
2. Smith River:
   A. **Designated Reach:** January 19, 1981 and November 16, 1990. The segment from the confluence of the Middle Fork Smith River and the North Fork Smith River to its mouth at the Pacific Ocean. The Middle Fork from its the headwaters to its confluence with the North Fork Smith River, including Myrtle Creek, Shelly Creek, Kelly Creek, Packsaddle Creek, the East Fork of Patrick Creek, the West Fork Patrick Creek, Little Jones Creek, Griffin Creek, Knopki Creek, Monkey Creek, Patrick Creek, and Hardscrabble Creek. The Siskiyou from its headwaters to its confluence with the Middle Fork, including the South Siskyou Fork of the Smith River. The South Fork from its headwaters to its confluence with the main stem, including Williams Creek, Eightmile Creek, Harrington Creek, Prescott Fork, Quartz Creek, Jones Creek, Hurdygurdy Creek, Gordon Creek, Coon Creek, Craigs Creek, Goose Creek, the East Fork of Goose Creek, Buch Creek, Muzzleloader Creek, Canthook Creek, Rock Creek, and Blackhawk Creek. The North Fork from the California-Oregon border to its confluence with the Middle Fork of the Smith River, including Diamond Creek, Bear Creek, Still Creek, the

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North Fork of Diamond Creek, High Plateau Creek, Stony Creek, and Peridotite Creek.

B. **Classification/Mileage:** Wild – 126 km (78 mi); Scenic – 50 km (31 mi); Recreational – 348 km (216 mi); Total – 524 km (325 mi).

C. **Managing Agencies**: California Resources Agency; Smith River National Recreation Area

Clean Water Act Section 303(d) Impaired Waters

Table 1 lists 303(d) impaired waters as of 2006 within the Klamath Network. Redwood Creek and the Klamath River in Redwood NP are listed due to impacts associated with upstream land use practices; in particular, these are road building, reduced forest cover as a result of logging, and dams. Redwood Creek is listed for continuing high levels of sediment and sedimentation impacting aquatic habitat and biota and the Klamath River is listed because of aquatic habitat degradation due to excessively warm water temperatures and high nutrient loads. In Whiskeytown NRA, Willow Creek (associated with past mining activities) and designated swim beaches of Whiskeytown Lake were previously listed as 303(d) impaired waters, however they do not appear on the CWA 2002 and 2006 lists for impaired waters in California (see http://www.waterboards.ca.gov/tmdl/docs/303dlists2006/final/statetcl_final303d.pdf).

Table 1. Klamath Network 303(d) listed impaired water bodies as of 2006.

303(d) Impaired Water	Pollutant/Stressor	TMDL Priority*
Klamath River (REDW)	Temperature	High
	Nutrients	High
Redwood Creek (REDW)	Temperature	Low
	Sedimentation/Siltation	Medium

* See the EPA web site: http://www.epa.gov/owow/tmdl/ for a description of the TMDL (Total Maximum Daily Loads) process.

Aquatic Species of Special Concern

In 2002, the Klamath Network began an inventory of vascular plants and vertebrate species of special concern in network park units (Acker et al. 2001). Aquatic vertebrate species of concern at the network-level include nine amphibian, five reptile, and four fish species. The study plan for this inventory is available at: http://www1.nature.nps.gov/im/units/klmn/inventories/download_files/inventory_study_plan.doc.

Locations of Active Monitoring Stations in the Klamath Network Region

The locations of geo-referenced climatic and hydrologic monitoring stations in or near Klamath Network park units are available in Appendix F – Water Quality (pages 12-15) of the Network's Phase II Report (Odion et al. 2005).

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Aquatic Resource Issues and Concerns

Klamath Network park units have completed a relatively thorough examination of their respective aquatic resource issues and concerns. These issues and concerns are generally shared among the parks relative to the type of aquatic resource (e.g., permanent wadeable cold-streams and permanent ponds and lakes). They have been identified in terms of five general vital signs categories and their associated stressors; a detailed summary is available in Chapter 3, pages 14-16 and 21-25.

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Chapter 2: Conceptual Ecological Models

The water quality and biotic communities of freshwater aquatic ecosystems are dynamically interconnected. Therefore, the elucidation of aquatic ecosystems can best be achieved by monitoring them as integrated systems (Warren 1979; Schindler 1987; Munn 1988), rather than monitoring water quality and biotic communities as separate components. A general conceptual model illustrating the role of water quality information for park conservation and reporting goals and its interconnectedness with biotic communities in aquatic ecosystems is presented below (Figure 2).

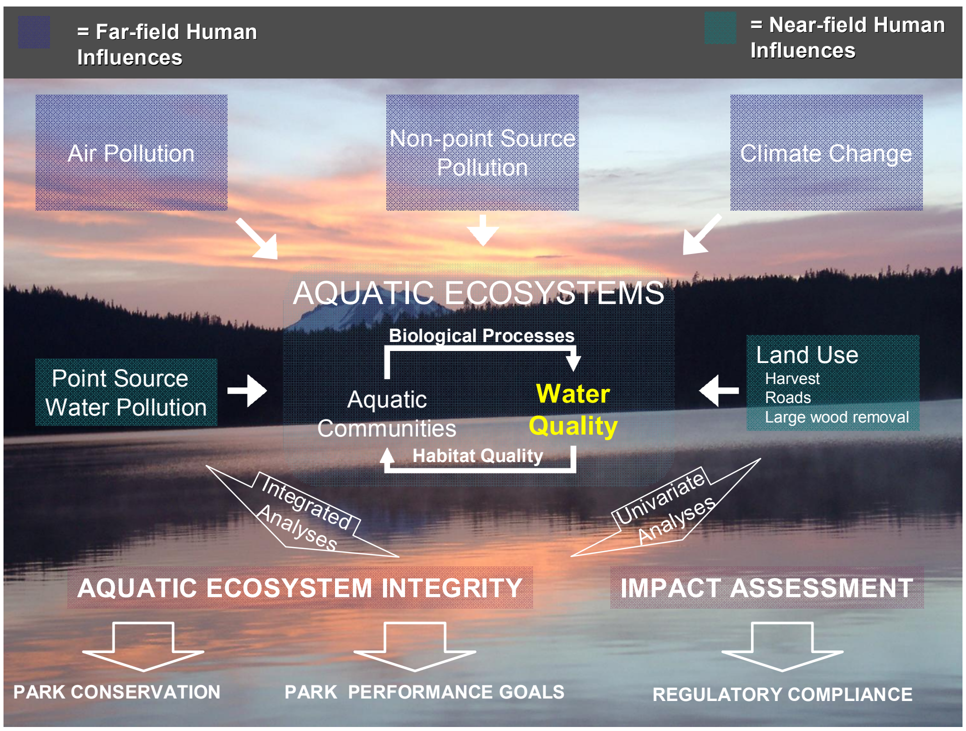

Figure 2. Conceptual ecological model showing the integral relationships between water quality and aquatic communities in aquatic ecosystems.

See the Klamath Network Vital Signs Monitoring Plan (Chapter 2) and Appendix F – Water Quality (Attachment III) of the Phase II Report (Odion et al. 2005) for additional conceptual models of network aquatic ecosystems.

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Chapter 3: Vital Signs

3.1. Network-wide Scoping, Identification, and Prioritization of Vital Signs for Aquatic Resource Monitoring

Purpose, Need, and Approach

Development of the Klamath Network integrated freshwater quality and aquatic community monitoring plan follows the guidance given in a May 2002 Memorandum to National Park Service Regional I&M Coordinators. The memo outlines the three-phase approach for developing a monitoring plan. Phase I of the Network's water resources and water quality assessment provides introductory and background resource and quality information for each park unit in the Network. Phase II (Odion et al. 2005) provides a more in-depth review of the aquatic resources and past water quality inventory, monitoring, and research activities in each park unit and discusses the process of identifying and prioritizing specific "vital signs indicators" (i.e., indicators of ecosystem health) to be monitored as part of a long-term water quality monitoring program. Phase III details the steps required to implement an integrated long-term monitoring program including development of: (1) monitoring objectives for each priority vital sign; (2) sampling protocols and sampling designs; and (3) a plan for data management, analysis, and reporting.

Water quality was identified during the Klamath Network's general ecosystems vital signs scoping process as an important element of the overall health of the Network's diverse ecosystems. The identification of general water quality vital signs was incorporated as one of the tasks of the Aquatic Group participating in the Network's third Vital Signs Workshop, held in 2004. The purpose of this workshop was to identify Level 1 and Level 2 Categories of the National Vital Signs Framework and to provide examples of vital signs and their measurements associated with these categories (see Phase II Report for details). A subsequent meeting focusing on identifying more specific water quality vital signs for each park unit also was completed in 2004.

Vital Signs Scoping

The Klamath Network began its vital signs monitoring scoping process in 1998. A detailed account of the process and key findings were reported in Chapter 3 of the Phase II report (Odion et al. 2005). Initial park-specific Vital Signs Workshops were held between 1998 and 2003 to begin to identify stressors that potentially impact park unit ecosystems. These workshops were followed in 2004 by three network-wide workshops focusing on (1) marine resources, (2) geology and soils, and (3) Level 1 and 2 categories of the National Vital Signs Framework. The purpose of these workshops was to identify general monitoring questions and broad-scale vital signs associated with specific ecosystems and categories (see Sarr et al. 2004, Appendix G, pages 4-17 including Table 1 for a complete list of National Vital Signs Framework Categories, available at http://www1.nature.nps.gov/im/units/klmn/MON_Phase_I.cfm).

General Water Quality Vital Signs Identified during the May 2004 Scoping Process

The dominant theme during the initial identification of network-wide general water quality vital signs was aquatic ecosystem health. The ability to (1) document improvement (or lack thereof) in the water quality of Clean Water Act section 303(d) listed streams, and (2) the ability of park unit managers to document progress toward achieving GPRA goal 1.a4 (i.e., that park units have unimpaired water quality) underscored the importance of identifying a suite of vital signs useful for effective water quality assessment. The need to fully inventory aquatic resources and document baseline and reference water quality conditions also were identified as important objectives in the development of a vital signs-based long-term water quality monitoring program. The vital signs initially identified included:

- Watershed budgets: A watershed budget is one method for monitoring water quality. It is an accounting of the inputs and outputs of water, nutrients, sediments, and chemicals passing through a particular watershed. Budgets vary considerably among watersheds. Typical monitored parameters include the concentration of major ions and isotopes, stream flow, groundwater hydrology, and continuous water temperature.
- Continuous water temperature measurement: Water temperature can be a useful indicator of the status and trends of aquatic ecosystems. Change in water temperature can be indicative of ecosystem impact due to climate change or other anthropogenic-derived perturbations. However, the intermittent monitoring of temperature can be problematic due to the significant temporal variation of temperature. Use of continuous recording devices is a preferred means of eliminating time-associated sampling variation.
- Groundwater quantity and quality: This vital sign refers to the monitoring of groundwater level and chemistry (including contamination). Monitored parameters include groundwater level and volume, pH, temperature, conductivity, trace organic compounds, and metals. Samples for analysis are obtained through purging and sampling groundwater wells.
- Reservoir elevation: Lakes that are hydrologically managed (i.e., water impounded by a dam) will have fluctuating water levels that can potentially affect lake food webs and ecosystem function. Therefore, changes in water surface elevation and storage capacity, as well as water inflow and discharge, should be part of the long-term monitoring of reservoirs.
- River invertebrate assemblages: The composition of an invertebrate assemblage can be a useful indicator of water quality and may change in response to the presence of exotic species, as well as changes in sedimentation rate, nutrient loading, composition of predator population, and climate. Two methods can be used to identify and document change: (1) comparing the species of a measured assemblage structure with species that may be indicative of a particular water quality condition (e.g., Stribling et al. 1998), and (2) using multivariate analysis to

compare a predicted invertebrate assemblage structure to a measured structure (e.g., Hawkins and Carlisle 2001; Lewis et al. 2001).

- Hydrology of springs and seeps (cold and hot): This vital sign includes documenting the location, volume, duration, and seasonality of flow of springs and seeps. Parameters are quantified by calculating physical/geometric metrics (i.e., water depth [maximum, minimum, average]; site length, and width) and discharge (flow quantity, duration, and peak) at each spring or seep.
- Stream flow/discharge: Stream flow is the measure of the flow of water in a stream at a specific time relative to (1) watershed routing mechanisms and water quality, (2) watershed land-use activities, and (3) natural and point-source discharges within the watershed. Stream discharge (Q) is defined as the unit volume of water passing a given point on a stream or river over a given time. It is typically expressed in cubic feet per second (cfs) or cubic meters per second (cms) and is based on the equation: $Q = A*V$, where A is the cross-sectional area of the stream at the measurement point and V is the average velocity of water at that point.
- Water chemistry: Information from monitoring water chemistry is used to evaluate water quality with respect to stressors such as atmospheric deposition, nutrient enrichment, and inorganic contaminants. The following parameters and ions are usually monitored: alkalinity, ammonia, bicarbonate, carbonate, calcium, chloride, fluoride, trace metals, nitrate, pH, potassium, silica, sodium, sulfate, total dissolved solids, total suspended solids, total nitrogen, and total phosphorous. In streams, concurrent discharge measurements allow data to be presented as mass flow (e.g., g/hr).
- Algal species composition and biomass: Algal species composition refers to the kinds of species present in a body of water. Algal biomass refers to the combined mass of the species. Certain species can indicate changes in water column nutrient input or water temperature. Algal composition is measured by examining algal assemblages, whereas algal biomass can be measured using chlorophyll ą concentrations or Secchi disk water clarity measurements.
- *Escherichia coli (E. coli)*: The presence of *E. coli* in a water sample is an indicator of fecal contamination. This bacterium can cause gastrointestinal distress and illness in humans and can be contracted by drinking contaminated water or by swimmers recreating in contaminated swimming areas. Determination of *E. coli* contamination is based on the density of the indicator organism in a water sample. The EPA requires that the concentration of *E. coli* in a water sample be no more than a geometric mean of 126 *E. coli* per 100 ml of fresh water, or 260 *E. coli* per 100 ml for any single sample.
- Exotic aquatic species community structure and composition: Introduced exotic aquatic species can affect the ecosystem dynamics of a water body and negatively impact naturally occurring native biota in affected systems. Monitoring the distribution (geographical location), abundance (number at each sampling location), and spread of exotic species can help managers understand the potential

environmental consequences of these organisms. Introduced exotic species of concern include fish (e.g., kokanee [*Oncorhynchus nerka*] in Crater Lake NP and brook trout [*Salvelinus fontinalis*] in western montane lakes and streams), as well as invertebrates (e.g., the New Zealand mud snail [*Potamopyrgus antipodarum*]).

- Native aquatic species community structure, composition, stability, and genetic integrity: This vital sign is associated with the overall health of native biota in water bodies of interest. Monitored parameters include the determination of the condition of native biotic communities based on metrics of species richness, composition, and trophic status, relative abundance, presence/absence, and genetics.
- Atmospheric deposition (wet and dry) of nitrogen, sulfur, and all major anions and cations: Atmospheric deposition is the process whereby air-borne particles, aerosols, and gases move from the atmosphere to the earth's surface. This vital sign is quantified by measuring snow-pack chemistry and direct measurements of wet (NADP/NTN) and dry (CASTNet) deposition. Fire (e.g., wildfire or controlled burns) is also a source of atmospheric deposition of pollutants and can reduce visibility in KLMN park units.
- Basic climatological measurements: Monitoring parameters associated with this vital sign will help park unit managers identify potential climate change. Basic climatological measurements include: temperature (maximum, minimum, and average), precipitation, relative humidity, wind velocity and pattern, surface pressure, and snow cover, depth, and water equivalent. The following are recommended standard metrics for these climatological variables: air temperature (°C), surface wind (m/s), and atmospheric humidity/water vapor (as percent, mixing ratio in g H_2O/kg-air, or concentration in g H_2O/m^3), surface pressure (hectopascals [hPa] or millibars [mb]), and snow cover and depth (water equivalent per km^2 and/or percent of area for cover and mm/cm for depth).
- Stream sediment transport: Sediment data, both suspended and bedload, are required for the evaluation of stream sediment yield with respect to (1) background environmental conditions (geology, soils, climate, runoff, topography, ground cover, and size of drainage area), (2) historic and current land use, and (3) erosion and deposition in channel systems. Additionally, understanding the temporal distribution of sediment concentration, size characteristics, and transport rates is crucial to the management of in-stream aquatic communities and riparian ecosystems. Standardized sediment sampling methods and the frequency of collection will be dictated by the hydrologic and sediment characteristics of the water body to be sampled, the required accuracy of the data, the funds available, and the proposed use of the collected data.

Also during the third 2004 vital signs scoping meeting, the Level 1 category, water, was divided into three Level 2 subcategories (i.e., hydrology, subterranean, and water quality). General conceptual models of freshwater and marine ecosystems (e.g., Attachment III of Appendix F – Water Quality, Phase II Report, available at http://www1.nature.nps.gov/im/units/klmn/MON_Phase_II.cfm) were used by participants to help organize and frame the discussions of ecosystem processes, dynamics, and linkages. Out of these discussions, general, broad-scale monitoring questions were developed and associated vital signs were identified for each Level 2 subcategory. Full details of the results of this process are available in Appendix F – Water Quality (Table 12, pages 49-52) of the Phase II Report available at (http://www1.nature.nps.gov/im/units/klmn/MON_Phase_II.cfm).

Priority Water Quality Vital Signs Associated with Monitoring Questions

In October 2004, the Klamath Network began the detailed assessment and narrowing of the identified water quality monitoring questions and vital signs. The process was initiated by sending an Aquatic Resources and Water Quality Questionnaire (see Appendix F – Water Quality (Attachment II) of the Phase II Report available at http://www1.nature.nps.gov/im/units/klmn/MON_Phase_II.cfm) to the Chief of Resources Management of each park unit. Park-specific information was sought in five basic categories: (1) identification of aquatic resources within park unit boundaries (i.e., marine, estuarine, lotic, lentic, palustrine, ice caves, and geothermal/hydrothermal); (2) a list of water bodies of particular importance or interest to the park unit management; (3) a list of past and current water quality monitoring efforts; (4) a list of water resource management and/or land use issues that impact resources from either within or outside each park unit; and (5) qualification of the level of knowledge and experience of park unit staff in monitoring water quality. Answers to the questionnaire categories were summarized into preliminary park-specific Vital Signs Tables that included columns for: (1) Aquatic Resource, (2) Potential Resource Stressors, (3) Potential Indicators of Stress, (4) Potential Monitoring Options, and (5) Stressor Priority.

The preliminary Vital Signs Tables were presented to representatives of each park unit at the Klamath Network Inventory and Monitoring Program Board of Directors Meeting (FY05) in Ashland, Oregon, December 1, 2004. A Water Quality Vital Signs Scoping Session was held that afternoon at which time the Vital Signs Tables were reviewed and refined. Session participants were separated into three working groups: (1) Crater Lake NP and Lassen NP; (2) Lava Beds NM and Redwood NP; (3) Oregon Caves NM and Whiskeytown NRA. The objectives of the small groups were, for each park unit, to: (1) identify specific water quality vital signs, ecosystem stressors associated with each vital sign, and associated monitoring options; and (2) prioritize aquatic resource vital signs. Final park-specific Vital Signs Tables were then developed based on feedback from the small groups, details of which are available in Appendix F – Water Quality (Tables 14-20, pages 59-70) of the Phase II Report (Odion et al. 2005).

The Vital Signs Tables created during this process include monitoring options useful in detecting potential resource changes due to stresses of natural or anthropogenic origin. These suggested options are not intended as a complete list of potential monitoring procedures useful for detecting ecosystem changes; the list of options can be amended as necessary during future program assessments. In addition to these options, several parameters will be required as core parameters (see http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/COREpar

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amFINwSIGpg.pdf) to be measured as part of the monitoring program. These core parameters include: (1) water temperature, (2) specific conductance (as well as salinity in marine systems), (3) pH, and (4) dissolved oxygen. At flowing sites, some measure of qualitative flows will be required. Estimates of water body stages or levels will be required at non-flowing/still freshwater sites. Guidance concerning these required parameters is available in the National Park Service Water Resources Division draft documents available at http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/COREparamFINwSIGpg.pdf and http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/wqPartC.pdf.

Park-level Vital Signs

Crater Lake National Park (CRLA): Crater Lake NP aquatic resources occur within and outside of the Mt. Mazama caldera. Crater Lake is the focus of most park visitors, and a long-term monitoring program of lake and inner-caldera streams and springs water quality has been active since June 1983. Geothermal sites deep in Crater Lake also are identified as an important resource within the caldera. Freshwater resources outside of the caldera include: (1) relatively small and shallow ponds, lakes, and wetlands; (2) Sphagnum Bog Research Natural Area (RNA); and (3) numerous streams and springs. Potential general stressors of Crater Lake, inner-caldera streams and springs, and ponds-lakes outside of the Crater Lake caldera, in order of priority, are: (1) climate change (e.g., temperature and precipitation regimes), (2) presence and extent of native/ introduced (invasive) aquatic biota, (3) atmospheric deposition of nutrients and pollutants, and (4) visitor use impacts - recreation and motorized boat use on Crater Lake. Vital Signs for perennial streams and springs outside of the caldera, in order of priority, are: (1) presence and extent of native/introduced (invasive) aquatic biota, (2) atmospheric deposition of nutrients and pollutants, and (3) land and non-recreational human use impacts – park operations. Cattle trespass is identified as a potential vital sign of Sphagnum Bog RNA. There also is concern that geothermal exploration near the CRLA boundary could negatively impact geothermal sites within the caldera.

Lassen Volcanic National Park (LAVO): Aquatic resources in Lassen NP can be grouped into two categories: (1) ponds, lakes, wetlands, and streams; and (2) geothermal/hydrothermal features such as hot springs and streams, fumaroles, and mudpots. Ponds and lakes, wetlands, and streams are grouped together because similar stressors impact each resource-type. Potential general stressors of these freshwater resources, in order of priority, are: (1) climate change (e.g., temperature and precipitation regimes), (2) atmospheric deposition of nutrients and pollutants, (3) presence and extent of native/introduced (invasive) aquatic biota (especially non-native trout and charr), and (4) visitor use impacts - recreational (e.g., hiking, backpacking, and camping) and non-recreational (park operations, e.g., parking lot and road maintenance and various construction projects). Visitor use impacts - recreational is identified as the major vital sign of geothermal/ hydrothermal resources in Lassen NP. Geothermal/hydrothermal resources have been and continue to be monitored as part of the USGS Volcano Monitoring Program.

Lava Beds National Monument (LABE): No permanent surface freshwater resources exist within the boundaries of Lava Beds NM; however, a few intermittent-ephemeral ponds occur. Aquatic resources in Lava Beds NM occur primarily as ice and water in permanent ice and seasonal wet caves and groundwater. Stressors of these resources include reduced precipitation associated with increased air temperatures and evaporation, and decreased relative humidity in caves. These changes could subsequently decrease the amount of ice in caves and the availability of water for Lava Beds NM biota. Because water is a precious commodity in Lava Beds NM, any change in water availability due either to stress of natural or anthropogenic origin could be quite detrimental to Lava Beds NM ecosystems. Stressors of anthropogenic origin include impacts due to climate change, geothermal exploration, agricultural land use (especially irrigation and use of chemicals), and timber harvest just outside of the Lava Beds NM boundary. The priority vital signs for Lava Beds NM aquatic resources are: (1) climate change (e.g., temperature and precipitation regimes), (2) groundwater, (3) agricultural chemicals in cave ice and water, and (4) extent of impact on water quality of activities associated with park unit development, visitor use, and water runoff from roads.

Oregon Caves National Monument (ORCA): The aquatic resources of Oregon Caves NM consist of an in-cave stream and springs, and surface streams. Stressors to in-cave resources include: (1) impacts due to climate change; (2) human actions that modify the cave environment, especially modification of cave openings; (3) visitor use impairments due to the introduction of inorganic and organic contaminants; (4) manipulation of the cave environment through the introduction of artificial light; (5) subsequent increase in algal growth in the cave and the introduction of contaminants (e.g., bleach) during cave algae control efforts; and (6) decrease in the amount and availability of in-cave water due to withdrawal of water from surface streams for fire suppression. Surface streams are susceptible to the effects of climate change, catastrophic fire, and debris flows. Cave Creek, a primary stream flowing through Oregon Caves NM, is also particularly susceptible to contamination by drain field leaching. The presence of grazing cattle near Oregon Caves NM streams may also contribute to the potential contamination of the Oregon Caves NM water supply. The priority vital signs of Oregon Caves NM aquatic resources are: (1) drain field contamination of Cave Creek, (2) cave environment relative to the modified cave opening, (3) visitor usage, and (4) cave environment relative to introduction of artificial light.

Redwood National and State Parks (REDW): Freshwater resources in Redwood NP include impaired streams (i.e., Redwood Creek and Klamath River), numerous unimpaired streams (e.g., Godwood Creek, Hayes Creek, Little Lost Man Creek, Mill Creek, Upper Prairie Creek, and Smith River), small ponds and wetlands, and several freshwater lagoons. Redwood Creek and Klamath River are listed under section 303(d) of the Clean Water Act for high water temperature and unacceptable levels of sedimentation and nutrients (see Table 1). Additional stressors include: (1) the presence of introduced invasive species, (2) upstream land use activities (e.g., timber harvest, use of herbicides, and controlled burns), (3) highway- and levee-related perturbations (e.g., road and culvert failures, runoff and toxic spills, and levee maintenance), (4) contamination from septic system leaching and illegal garbage/trash dumping, and (5) riparian/bank disturbance associated with recreational fishing. Park watershed rehabilitation activities and in-channel gravel extraction additionally impact Redwood Creek. The unimpaired sites will be useful for determining baseline water quality characteristics and range of natural variation of Redwood NP streams. Immediate stressors to these systems include runoff and toxic spills from State Highway 229 and U.S. Highway 101 and groundwater draw-down at the Mill Creek Campground. The priority vital signs for Redwood NP freshwater resources are: (1) 303(d) listed streams (Redwood Creek and Klamath River), (2) upstream land cover and use, (3) recreational fishing, and (4) presence and extent of introduced exotic biota.

Whiskeytown National Recreation Area (WHIS): Whiskeytown NRA aquatic resources include Whiskeytown Lake, perennial streams, mineral springs, permanent and intermittent small-shallow ponds, and marshes. Water-related activities (e.g., boating, sailing, water skiing, kayaking, swimming, fishing, etc.) are the primary recreational focus of visitors to Whiskeytown Lake and are potential stressors of reservoir water quality. Additional stressors related to human activity include park unit sewage treatment and wastewater discharge by surrounding communities, marijuana farming, heavy metals contamination from past mining operations on the upstream sections of reservoir tributaries, and water level fluctuations caused by reservoir dam operations. As is the case with many large water bodies in the western USA, the introduction of non-native, invasive flora and fauna species impacts the native biota of Whiskeytown Lake. Impacted perennial streams have been affected by human-related activity (e.g., past mining operations, treatment and disposal of human waste, marijuana farming, recreation, deteriorating abandoned logging roads, gravel injection, waste rock disposal, prescribed/natural fires and related activities, floods, and introduced non-native, invasive biota). The unimpaired perennial streams in Whiskeytown NRA can be used to determine the baseline lotic water quality conditions and range of natural variation. However, these streams can also be affected by perturbations of natural and anthropogenic origin. Whiskeytown NRA also contains a complex of mineral springs that support a small, indigenous population of Howell's alkali grass (*Puccinellia howellii*), which is listed by the California Native Plant Society as rare and endangered. Stressors to this resource include: (1) littering and garbage dumping, trampling, and off-road vehicle use; (2) change in hydrology; (3) State Highway 299 maintenance and contamination/pollution due to vehicle use and accidents; and (4) competitive exclusion by native saltgrass (*Distichlis spicata*) due to altered soil and water chemistry. Little is known about the various permanent and intermittent small-shallow ponds and marshes that occur in Whiskeytown NRA. They, like the unimpaired perennial streams, are susceptible to various types of stress of natural and anthropogenic origin. The priority vital signs of Whiskeytown NRA aquatic resources are: (1) extent of human impacts such as heavy metals contamination associated with from past mine operations and tailings; (2a) park unit sewage treatment and disposal; (2b) septic tanks, garbage/trash, and marijuana farming; and (3) extent and occurrence of natural and prescribed fire.

Details of park-specific vital signs for freshwater resources, their potential stressors, and associated monitoring options are available in Appendix F – Water Quality (Tables 14-20, pages 59-70) of the Phase II Report (Odion et al. 2005).

Network-level Vital Signs Assessment

Priority Aquatic Resource Monitoring Questions and Vital Signs: Two of the 10 most important network-wide vital signs identified at the 2005 vital signs prioritization meeting were aquatic resource-focused. The top 10 (out of 172) candidate vital signs were selected based on the total rating assigned to them by the individuals who participated in the Klamath Network vital signs - monitoring question rating process. The two aquatic resources vital signs were (1) water quality characteristics of surface and subterranean freshwater resources, and (2) aquatic biota and communities. The monitoring questions for each vital sign were, respectively, (1) what are the status and trends of surface waters and pollutants, and (2) what are the status and trends in structure and composition of locally limited (i.e., focal) aquatic communities?

Aquatic Resource Vital Signs Categories: Five general vital signs categories (Table 2) were identified as potentially affecting Klamath Network park unit freshwater resources: (1) atmospheric deposition of nutrients (e.g., nitrogen and phosphorus) and pollutants (e.g., mercury, persistent organics, flame retardants, water-repellent coatings, etc.), (2) presence and extent of non-native/introduced (invasive) aquatic biota (e.g., bullfrogs, exotic fish, invertebrates, algae, etc.), (3) climate change (e.g., changes in air and water temperature regimes and the timing and longevity of precipitation events and snow pack, etc.), (4) visitor use impacts – recreational, and (5) land and non-recreational human use impacts. Visitor use impacts – recreational was divided into four types of impact subcategories ranging from general impacts in the more developed and maintained areas in park units to backcountry impacts caused by activities such as hiking, backpacking, and camping. The land and non-recreational human use impacts category was divided into 15 types of impact subcategories representing activities that include road construction and maintenance, treatment and deposition of human waste, dam operation and maintenance, agriculture, and past and present resource extraction operations (e.g., mining, timber harvest, geothermal exploration). A relatively high number of vital signs categories and subcategories (Table 3) were associated with permanent lentic (12 of 22; 55%), permanent lotic (15 of 22; 68%), and unique water resources (10 of 22; 45%). Permanent lotic systems were also identified as especially associated with land and non-recreational human use impact subcategories (i.e., 10 of 15 compared to 6 of 15 for lentic and unique water resources; Table 3). The vital sign categories and subcategories associated with cave water resources (e.g., ice, streams, and springs) were climate change, visitor use, manipulation of the cave environment, park unit operations, nearby agricultural activities, and activities associated with fire suppression. Geothermal – hydrothermal resources were identified as being generally affected by visitor use and geothermal exploration occurring near park unit boundaries.

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Table 2. General vital signs categories and subcategories and their applicability in each Klamath Network park unit.

Vital Sign	CRLA	LAVO	LABE	ORCA	REDW	WHIS
1. Atmospheric deposition of nutrients and pollutants	X	X			X	X
2. Presence & extent of native/introduced (invasive) aquatic biota	X	X			X	X
3. Climate change (e.g., temperature & precipitation regimes)	X	X	X	X		X
4. Visitor use impacts – recreational						
A. General impacts		X	X	X		
B. Hiking, backpacking, camping, horses, mountain bicycles	X	X				X
C. Motorized boats & boat-related activities	X					X
D. Swimming, fishing, etc.					X	X
5. Land & non-recreational human use impacts						
A. Park operations (construction, development, parking lot/road & levee maintenance)	X	X	X	X	X	X
B. Roads: construction, maintenance, failure, culverts, runoff, spills	X	X	X		X	X
C. Past mining operations/heavy metals						X
D. Dam operations, water-level & sediment flux						X
E. Sewage treatment, wastewater discharge, septic & drain field contamination				X	X	X
F. 303(d) listed water bodies					X	
G. Former mill site & operations					X	
H. Fire: wild & prescribed; suppression				X	X	X
I. Timber harvest & operations (including herbicide application)			X		X	
J. Agriculture: contamination by fertilizers, herbicides & pesticides; irrigation			X			X
K. Manipulation of cave environment (especially light & control of algae)				X		
L. Geothermal exploration & activities near park boundary	X		X			
M. Litter & garbage dumping					X	X
N. Vehicle parking & off-road use						X
O. Impacts associated with trespassing cattle (grazing & trampling)	X			X		

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

Table 3. General vital signs categories and subcategories and their applicability to each freshwater resource-type in Klamath Network park units [p = permanent; Lentic = primarily ponds and lakes; Lotic = primarily streams; Geo/Hydro = Geothermal/Hydrothermal; unqRes = unique resource including intermittent ephemeral ponds and seasonal ice caves (LABE), mineral springs complex (WHIS), and Sphagnum Bog Research Natural Area (CRLA)].

Vital Sign	pLentic	pLotic	Geo/Hydro	Caves	unqRes
1. Atmospheric deposition of nutrients & pollutants	X	X			X
2. Presence & extent of native/introduced (invasive) aquatic biota	X	X			X
3. Climate change (e.g., temperature & precipitation regimes)	X	X		X	X
4. Visitor use impacts – recreational					
A. General impacts			X	X	
B. Hiking, backpacking, camping, horses, mountain bicycles	X	X			X
C. Motorized boats and boat-related activities	X				
D. Swimming, fishing, etc.	X	X			
5. Land & non-recreational human use impacts					
A. Park operations (construction, development, parking lot/road & levee maintenance)	X	X		X	
B. Roads: construction, maintenance, failure, culverts, runoff, spills		X			
C. Past mining operations/heavy metals	X	X			
D. Dam operations, water-level & sediment flux	X	X			
E. Sewage treatment, wastewater discharge, septic & drain field contamination	X	X			
F. 303(d) listed water bodies	X				
G. Former mill site & operations	X				
H. Fire: wild & prescribed; suppression		X		X	
I. Timber harvest & operations		X			X
J. Agriculture: fertilizers, herbicide & pesticide contamination, irrigation		X		X	X
K. Manipulation of cave environment (especially light & control of algae)				X	
L. Geothermal exploration & activities near park boundary			X		X
M. Litter & garbage dumping		X			X
N. Vehicle parking & off-road use					X
O. Impacts associated with trespassing cattle (grazing & trampling)		X			X

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Vital Signs Prioritization: Vital signs were prioritized for each park unit by park staff relative to the perceived importance of including each vital sign category as part of an aquatic resources monitoring program. The prioritization of vital signs varied among the units:

1. Crater Lake NP identified each of the five general vital signs categories as important for monitoring the park's lentic and lotic resources;
2. Lassen NP did not identify any of the land and non-recreational human use impact subcategories as potentially affecting the park's water resources;
3. Climate change was identified as the top priority vital sign category at Lava Beds NM, followed by four types of land and non-recreational human use impacts (i.e., park unit operations, timber harvest/operations, agriculture, and geothermal exploration);
4. Land and non-recreational human use impacts (especially associated with human waste disposal and timber harvest), climate change, and visitor use impacts – recreational (i.e., general impacts) were identified as priority vital signs categories for Oregon Caves NM;
5. Redwood NP did not identify atmospheric deposition of nutrients and pollutants as a priority vital sign categories for the park's freshwater and marine resources;
6. The only vital sign category identified as important for Whiskeytown NRA aquatic resources was land and non-recreational human use impacts, which included three priority subcategories (i.e., past mining operations, dam operation and water-level flux, and impacts due to fire and fire suppression).

An index was created to determine the perceived importance of each general vital sign category at the network-level. The index was calculated for each vital sign by adding the priority rating (i.e., 1–4, with 1 being the highest priority) assigned to the vital sign by each park unit. If a park unit did not assign a rating to a vital sign, then a rating of 5 was assigned to that vital sign for that unit. If a park unit assigned two or more ratings to a vital sign (e.g., CRLA atmospheric deposition = 3/2, LABE land and non-recreational human use impacts = 4/2a/3/2b) then the ratings for that vital sign were averaged. The average index for all park units for each general vital sign was calculated as:

Vital Sign ranking = [CRLA + LAVO + LABE + ORCA + REDW + WHIS]/6 park units.

For example:

1. atmospheric deposition = [(3+2)/2+2+5+5+5+5]/6 = **4.1**
2. land use = [3+5+(4+2+3+2)/4+(1+2)/2+(1+4+1+2+2)/5+(1+2+2+3)/4]/6 = **2.7**

A lower ranking indicated vital signs perceived to be more important as potential sources of aquatic resource perturbation. The ranking outcomes were:

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1.	Climate change:	mean = 2.7; median = 1.5; 5 of 6 park units
2.	Land use impacts:	mean = 2.7; median = 2.4; 5 of 6 park units
3.	Native/introduced biota:	mean = 3.8; median = 4.0; 3 of 6 park units
4.	Visitor use impacts - recreational:	mean = 4.0; median = 4.0; 4 of 6 park units
5.	Atmospheric deposition:	mean = 4.1; median = 5.0; 2 of 6 park units

Monitoring Questions, Potential Indicators of Resource Stress, and Associated Monitoring Options: A monitoring question was developed for each of the five general aquatic resource vital signs categories (Table 2). Each question was general in scope to be applicable to all park units. Next, a list of potential stress indicators (i.e., characteristics that can be measured and are useful indicators of change and/or perturbation) for each vital sign category was created. Indicators were chosen that could be used to answer each monitoring question. Finally, a list of potential monitoring options consisting of a parameter or set of parameters to be sampled and useful for quantifying resource change and/or perturbation due to ecosystem stress was created. This process created a relatively detailed outline of vital signs monitoring questions, stress indicators, and monitoring options:

1. <u>Basic information that would be helpful to have for each resource-type prior to implementation of a monitoring program</u>:
   A. Complete inventory (or as complete as possible) of sites in each park unit.
   B. Status and trends:
      1) Analyze data to elucidate the present physical, chemical, and biological characteristics of (at least) a subset of sites; and
      2) Determine the present variability among sites.
   C. Identify sites potentially not affected by impacts due to recreational visitor use, park unit operations, or nearby past and present land use activities. These sites will be potentially useful for determining, at least in a relative sense, the characteristics and variation among 'pristine' sites to which impacted sites can be compared.
2. <u>Climate change (e.g., temperature and precipitation regimes)</u>:
   A. Monitoring question: What impacts do global and local changes in climate have on Klamath Network park unit aquatic resources (especially regarding such parameters as the timing and extent of precipitation, water and air temperature ranges, air currents, relative humidity, evaporation rates, ozone-levels, and UVB radiation flux and attenuation); and how do these impacts affect resource condition, quality, and ecosystem dynamics?
   B. Indicators of stress:
      1) Change in climate-related parameters such as (a) water and air temperature, (b) relative humidity, (c) timing and amount of precipitation (rain and snow), (d) water-level, (e) flow and discharge rates, (f) ozone levels, (g) UVB radiation flux and attenuation and ocean processes (e.g., upwelling, wave action, nearshore currents).
      2) Change in the timing, longevity and physical characteristics of intermittent ephemeral ponds (primarily at LABE).

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C. Monitoring Options:
   1) Measure water and air temperature, relative humidity, precipitation, water-level, flow and discharge rates, ozone levels, and UVB radiation flux and attenuation;
   2) Quantify trends of wave action, upwelling, and nearshore currents; Measure for change beyond normal statistical variation;
   3) Quantify the timing, depth, and duration of snow pack, and the timing and extent of snow melt;
   4) Identify and quantify ice sources and intermittent ephemeral ponds (LABE);
   5) Determine extent of ice sources and measure ice-levels, evaporation rates, concentrations of total carbonates and calcite solubility (LABE and ORCA);
   6) Quantify the timing, longevity and physical characteristics of intermittent ephemeral ponds (LABE).

3. <u>Land and non-recreational human use impacts</u>:
   A. Monitoring question: How do land use activities (past, present, and within and outside of Klamath Network park units) affect park unit aquatic resources, and how do these activities impact resource condition, quality, and ecosystem dynamics?
   B. Indicators of stress:
      1) Change in sedimentation/siltation and turbidity;
      2) Changes in the distributions and composition of aquatic biota;
      3) Disturbance (e.g., trampling, rutting, erosion) of stream banks and channels, pond and lake shorelines, and wetted areas;
      4) Presence of and/or change in the concentrations of hydrocarbons and other motor vehicle derived contaminants;
      5) Change in water temperature and dissolved oxygen level;
      6) Change in channel morphology (e.g., bank and channel erosion), as well as flow and discharge rates;
      7) Presence of and/or change in the concentrations of heavy metals and other contaminants (e.g., herbicides, pesticides, dioxin);
      8) Disruption of native anadromous salmonid passage;
      9) Change in nutrients (e.g., nitrogen and phosphorus) and primary productivity;
      10) Presence of and/or change in bacterial indicators of fecal contamination, *Giardia*, and *Cryptosporidium*;
      11) Changes in the depth and quantity of groundwater;
      12) Presence of and/or changes in the abundance of light-adapted biota as well as contaminants such as hydrogen peroxide and sodium hypochlorite in caves;
      13) Presence of and/or changes in the amount of litter and garbage at or near resource sites.
   C. Monitoring Options:
      1) Collect sediment cores to determine historical and contemporary sedimentation rates. Measure turbidity, bedload, flow and discharge rates, and water-level;
      2) Measure water temperature, dissolved oxygen level, and nutrient and chlorophyll-ą concentration;

3) Quantify the presence and composition of aquatic biota and use rapid bioassessment methods to identify and quantify impact;
4) Quantify the presence and concentrations of heavy metals and other contaminants (e.g., herbicides, pesticides, dioxin, hydrogen peroxide, sodium hypochlorite) in water and/or tissue samples;
5) Analyze water samples for hydrocarbons and other motor vehicle derived contaminants;
6) Quantify the presence and concentrations of bacterial indicators of fecal contamination, *Giardia*, and *Cryptosporidium* in water samples;
7) Quantify the abundances of light-adapted biota in caves;
8) Measure groundwater depth and quantity;
9) Map and photo-archive beach, shoreline, bank and channel profiles and monitor for disturbance (e.g., trampling, soil compaction, rutting, erosion, de-vegetation);
10) Measure ice-levels and the quantity and availability of water in caves;
11) Measure the presence and amount of litter and garbage at or near resource sites.

4. <u>Presence and extent of native/introduced (invasive) aquatic biota</u>:
   A. Monitoring question: What impact do introduced/invasive non-native aquatic biota have on the distributions and survival of native aquatic biota, and on the biotic community and ecosystem dynamics of Klamath Network park unit aquatic resources?
   B. Indicators of stress:
      1) Change in the (a) distributions, (b) abundances, (c) percent area occupied (PAO), and (d) community organization and structure of native and non-native introduced/invasive biota of concern
   C. Monitoring Options:
      1) Quantify trends of native and introduced (invasive) aquatic biota including: (a) distributions, (b) abundances, (c) PAO, (d) community organization and structure, and (e) rates of recruitment and mortality;
      2) Quantify the condition and quality of the habitats occupied by native biota of concern.
5. <u>Visitor use impacts - recreational</u> including (a) tour-related impacts; (b) hiking, backpacking, and camping; (c) stock (horse) and mountain bicycle use; (d) swimming, sun-bathing, and picnicking; (e) recreational fishing; and (f) motorized boats and boat-related activities:
   A. Monitoring question: How do the recreational activities of visitors affect Klamath Network park unit aquatic resources and how do these activities impact resource condition, quality, and ecosystem dynamics?
   B. Indicators of stress:
      1) Change in shoreline/bank erosion and concomitant change in nearshore sedimentation rates and siltation;
      2) Change in shoreline/bank soil compaction, trampling, and de-vegetation;
      3) Change in the distributions and composition of aquatic macroinvertebrates;

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        4) Presence of and/or change in the concentrations of bacterial indicators of fecal contamination;
        5) Presence of and/or change in the amounts of litter and inorganic/organic contaminants.
    C. Monitoring Options:
        1) Quantify shoreline/bank condition and measure, map, and photo-archive indicators of erosion and impact (e.g., (a) sedimentation/ siltation, (b) soil compaction, (c) de-vegetation);
        2) Collect sediment cores to document historical and contemporary sedimentation rates;
        3) Measure water clarity and turbidity;
        4) Quantify macroinvertebrate species presence and composition in all aquatic habitats;
        5) Measure chlorophyll-ą concentration in phytoplankton and periphyton samples (as a proxy for primary productivity);
        6) Determine, in water samples, the presence and concentrations of bacterial indicators of fecal contamination;
        7) Quantify the presence and amount of litter, as well as inorganic/organic contaminants in caves, and monitor for change.

6. <u>Atmospheric deposition of nutrients (e.g., nitrogen and phosphorus) and pollutants (e.g., mercury, persistent organics, flame retardants, water-repellent coatings, etc.)</u>:
    A. Monitoring question: How does the atmospheric deposition of nutrients and other contaminants affect the water quality and ecosystem dynamics of Klamath Network park unit aquatic resources?
    B. Indicators of stress:
        1) Presence of and/or change in the concentrations of air-borne nutrients and pollutants;
        2) Change in primary productivity;
        3) Change in the presence and composition of aquatic macroinvertebrates, especially species negatively affected by air-borne pollutants.
    C. Monitoring Options:
        1) Wet/dry chemistry: (a) rain and snow precipitation samples, (b) snow core samples;
        2) Analyze water samples for nitrogen and phosphorus concentrations;
        3) Analyze tissue samples (highest trophic-level possible) for the presence and concentrations of pollutants of interest;
        4) Determine the concentration of chlorophyll-ą in phytoplankton and periphyton samples (as a proxy for primary productivity);

Determine the presence and composition of aquatic macroinvertebrates, and use rapid bioassessment methods to identify and quantify impact.

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Chapter 4: Sampling Design

4.1. Sampling Design and Rationale for Selecting Design

Perennial ponds, lakes, and wadeable cold-streams are the dominant surficial aquatic ecosystems throughout the Klamath Network and have been selected as the focal aquatic ecosystems to be monitored. In general, aquatic ecosystems are complex adapting systems whose characteristics are influenced by local as well as regional environmental conditions (Hynes 1975; Vannote et al. 1980; Larson et al. 1994, 1999; Frissell and Bayles 1996; Allan and Johnson 1997). They also can act as drivers that influence local and landscape-level ecosystem modification (Walsh et al. 2003; Benda et al. 2004). Therefore, freshwater ecosystems can be useful indicators of impacts or changes due to various types of environmental perturbation across the landscape. Five basic stressors (i.e., climate change, atmospheric deposition of nutrients and pollutants, presence or introduction of non-native and invasive biota, non-recreational land use practices within and external to parks, and visitor recreational activities within parks) have been identified as potentially impacting the water quality and aquatic communities of Klamath Network freshwater ecosystems. Research has documented that physical, chemical, and biological characteristics of lakes and streams (e.g., water-level and temperature, discharge and flow rate, NO_3 concentration, productivity) can be affected by and serve as indicators of climate change (McKnight et al. 1996; Williams et al. 1996; O'Reilly et al. 2003). Additional research documents the potential of aquatic ecosystem characteristics as early and historical indicators of the impacts of atmospheric deposition (Carpenter et al. 1998), the presence or introduction of invasive aquatic biota (Boersma et al. 2006), and anthropogenic stress (Schindler 1987; Spencer 1991).

The Klamath Network has chosen to develop and implement a sampling design that integrates the monitoring of water quality and aquatic communities. This type of whole-ecosystem focus in long-term monitoring is quite efficient and useful, especially when confronted with multiple potential ecosystem stressors (Schindler 1987). Whole-ecosystem monitoring provides resource managers with the flexibility of attending to and sampling a suite of physical, chemical, and biological characteristics that together can provide a complete expression of baseline conditions and trends of the ecosystems. The water quality and community parameters to be sampled will be useful for detecting the status and trends of aquatic ecosystems within a range of natural variation or potential ecosystem change due to one or more natural and/or anthropogenic stressors. The ultimate outcome of this monitoring program will be that Klamath Network parks will develop, over time, a detailed understanding of the freshwater ecosystems being monitored and an extensive database that resource managers can use to effectively predict spatial and temporal dynamics of the conditions of Klamath Network freshwater ecosystems.

The fundamental goal of this integrated plan is to provide guidance for monitoring the status and trends of the water quality and aquatic communities of Klamath Network surficial freshwater ecosystems, specifically: (1) perennial montane ponds and lakes (CRLA, LAVO), (2) perennial montane wadeable cold-streams (CRLA, LAVO, WHIS), (3) perennial coastal and Coast Range wadeable cold-streams (REDW), and (4) cave-associated wadeable cold-streams (ORCA). Measurable objectives of the plan include:

A. Objective 1: Sample a suite of physical, chemical, and biological parameters (see subsection 4.4.) that can be used to determine site-specific and ecosystem-level baseline water quality and aquatic community conditions of the freshwater systems being monitored.

B. Objective 2: Develop and maintain a database and associated metadata (see Chapter 6) for storing data derived from the measurement and analysis of physical, chemical, and biological parameters sampled for each monitored ecosystem.

C. Objective 3: Analyze data using a suite of statistical tools (see Chapter 7) useful for documenting the status and trends of the ecosystems being monitored; and based on this analysis identify for each ecosystem any possible site-specific and ecosystem-level deviance beyond natural variation in baseline conditions.

D. Objective 4: Report the results of status and trend analysis annually and provide ongoing synthesis of annual reports no more than one year after the completion of each 3-year monitoring cycle (see Chapter 7).

A split-panel, revisit design (Urquhart et al. 1998; McDonald 2003; see Table 4.1 of the Klamath Network Vital Signs Monitoring Plan) will be used to sample these ecosystems. The panels consist of randomly selected index sites that will be visited and sampled every third year and randomly selected survey sites that will be visited and sampled once every 30 years. A limited number of subjectively selected judgment sites also will be visited and sampled once every third year. Judgment sites will be selected based on a perceived and justifiable need to include them as part of the monitoring program. They will allow managers to sample sites of particular interest that: (1) have been historically sampled and would benefit from continued sampling, (2) have attributes and/or characteristics of ecological interest, (3) have some impact (e.g., visitor-attributed disturbance) or perturbation (e.g., contamination due to atmospheric deposition of nutrients or tailings from past mining activities) that requires long-term monitoring, and/or (4) need to be sampled due to a statutory directive or requirement (e.g., Clean Water Act section 303[d] sites).

The sampling design will utilize a 3-year rotation in which parks and ecosystems will not be visited and sampled in the same years (see Table 4). In the first year, only streams will be sampled at Redwood NP, Crater Lake NP, and Oregon Caves NM; in year 2, only streams will be sampled at Whiskeytown NRA, Lassen NP, and Oregon Caves NM; and in year 3, only ponds and lakes at Crater Lake NP and Lassen NP, and 1 freshwater lagoon at Redwood NP will be sampled. This design will accommodate the sampling of similar ecosystems in the same year(s) and allow a greater number of sites to be sampled

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per ecosystem type in each park. We also have grouped relatively low elevation parks (e.g., Redwood NP and Whiskeytown NRA) with relatively higher elevation parks (e.g., Crater Lake NP and Lassen NP) in the first two years of sampling so that lower elevation sites will be available for sampling early in the summer field season when higher elevation sites may not be accessible. In many years, this will allow the summer field season to begin in mid-June instead of mid- to late July if only higher elevation locations were to be sampled. However, since only montane ponds and lakes will be sampled in year 3, all but one sampling site (i.e., Redwood NP freshwater coastal lagoon) will be located in higher elevation parks during that sampling year.

Panel designs that include revisited sites (e.g., index sampling sites) and sites that may or may not be revisited (e.g., survey sampling sites) are, over time, effective and provide adequate power for detecting the status and trends of ecosystem condition (Urquhart et al. 1998; Urquhart and Kincaid 1999). The prime advantages of randomly selecting index and survey sampling sites are: (1) probabilistic sampling makes it possible to use a reasonable and cost-effective proportion of sites for enumerating the status and trends of relatively extensive resources (USEPA, Aquatic Resources Monitoring – Design, General Overview of Probabilistic Surveys, http://www.epa.gov/nhrlsup1/arm/designpages/monitdesign/survey_overview.htm), and (2) straight forward statistical inferences can be made to the entire population from which the sampling sites are selected (McDonald 2003).

Table 4. Number of sites to be sampled during the first three years of monitoring in Klamath Network parks. For wadeable cold-streams: numbers in parentheses equal number of streams; numbers not in parentheses equal number of 100-m sampling sites.

Year	Ecosystem	Park	Judgment (J)	Index (I)	Survey (S)	Total (I&S)	All Sampling Sites (J + I&S)
1	Wadeable cold-streams	REDW	(2) 4	(6) 12	(7) 14	(13) 26	(15) 30
		ORCA	(1) 3	—	—	—	(1) 3
		CRLA*	(2) 4	(6) 12	(7) 14	(13) 26	(15) 30
2	Wadeable cold-streams	WHIS	(1) 3	(4) 12	(5) 15	(9) 27	(10) 30
		ORCA	(1) 3	—	—	—	(1) 3
		LAVO	(1) 2	(6) 12	(7) 14	(13) 26	(14) 28
3	Ponds and Lakes	REDW	1	—	—	—	1
		LAVO	1	14	14	28	29
		CRLA	—	14	14	28	28

* includes two wadeable cold-stream sampling sites and two fen sampling sites

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4.2. Site Selection, Criteria, and Procedures for Selecting Sampling Locations

Perennial Wadeable Cold-Streams

The sampling frame for streams will be a list of all named perennial cold-streams derived from a GIS layer that includes all cold-streams in each park, except at Oregon Caves NM where only one stream (Cave Creek) will be considered for monitoring. There will be five park-focused sampling frames: (1) Crater Lake NP streams, (2) Lassen NP streams, (3) Redwood NP streams, (4) Whiskeytown NRA streams, and (5) the Oregon Caves NM stream associated with a cave-complex.

The target population for each sampling frame will be composed of two or three sampling sites located within each stream selected from the list of named streams. The number of sampling sites per stream will vary by park (i.e., Crater Lake NP, Lassen NP, and Redwood NP = 2 sampling sites/stream; Whiskeytown NRA and Oregon Caves NM = 3 sampling sites/stream).

The criteria for stream and sampling site selection, which have been selected to emphasize accessibility and safety (see discussion in the Klamath Network Vital Signs Monitoring Plan), include:

1. Streams will be <1000 m from an active road or trail;
2. Sampling sites will be 100-m sections of stream length <1000 m from an active road or trail;
3. Sampling sites will be located on slopes <30 degrees.

Streams and sampling sites are selected separately for each park. Stream and sampling site selection will proceed as follows:

1. A list of named streams considered suitable for sampling (hereafter called "suitable streams") is created based on the criteria above;
2. GRTS, a software plug-in for the statistical application R that takes an input GIS polygon or line feature and populates spatially balanced points within or along streams, is used to populate points along suitable streams;
3. Subjectively selected judgment streams are identified and populated with two sampling points that are either non-randomly appointed or randomly selected;
4. Judgment streams are then removed from the list of suitable streams;
5. Four over-run points also are identified along each judgment stream to be used if for any reason the initial two points are judged to be unsuitable for sampling;
6. All remaining "suitable streams" on the list are used as an input in GRTS to randomly select all index and survey points to be sampled and over-run points in each park;
7. GRTS is then used to separate survey points into 10 groups, each group representing points to be sampled at different time steps from 1 to 10 (i.e., Time 1 = 1st sampling year; Time 2 = 2nd sampling year, etc.);

8. A point represents the center of a 100-m sampling section on a stream that is determined by measuring 50 m downstream and upstream from the center-point; these 100-m sections will be considered to be sampling sites;
9. All judgment, index, and survey points are then symbolized and added to respective park maps.

Six wadeable cold-streams and one fen have been selected as judgment sites. The rationale and justification for selecting these sites are:

1. Sun Creek (Crater Lake NP): this stream was selected because it contains threatened bull trout, lies along a major access road to the park with potential visitor use impacts, and has a history of ecological restoration and aquatic study;
2. Sphagnum Bog (Crater Lake NP): this site was selected because it is in a Research Natural Area, is representative of relatively uncommon high elevation bogs, and is sensitive to perturbation;
3. Hot Springs Creek (Lassen NP): this stream was selected because it is representative of geothermally-influenced streams located within the park; the creek may be subject to impacts from existing infrastructure, such as buildings, a road, a leach field, camping, and visitor day use; and a unique fen is associated with the creek’s riparian area;
4. Cave Creek (Oregon Caves NM): this stream was selected because it flows through the monument’s cave-complex, has been previously sampled, and is prone to primary visitor use impact;
5. Godwood Creek (Redwood NP): this stream was selected because it is relatively pristine and is the only stream in a roadless old-growth area in the park;
6. Redwood Creek (Redwood NP): this stream is a Clean Water Act 303(d) stream listed for temperature and sedimentation/siltation;
7. Willow Creek (Whiskeytown NRA): this stream was selected because it has been previously sampled and monitored for heavy metals contamination due to past mining activities.

Montane Ponds and Lakes

Lentic ecosystems in Klamath Network parks occur almost exclusively in Crater Lake NP and Lassen NP, although several freshwater coastal lagoons and artificial ponds are present in Redwood NP and a large reservoir (Whiskeytown Lake) is located in Whiskeytown NRA. The sampling frames for lentic ecosystems will be:

1. Crater Lake NP GIS layer of perennial ponds and lakes outside of the Crater Lake caldera;
2. Lassen NP GIS layer of perennial ponds and lakes;
3. One freshwater coastal lagoon at Redwood NP.

The target population, except for the freshwater lagoon, will be individual ponds and lakes (hereafter called “sampling sites”) at Crater Lake NP and Lassen NP.

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The criteria for pond and lake selection include:

1. Ponds and lakes that are <25 m maximum depth;
2. Ponds and lakes that are <1000 m from a travelable road or trail;
3. Ponds and lakes located in an area where slopes are <30 degrees.

Ponds and lakes will be selected separately for each park. Pond and lake selection will proceed as follows:

1. Suitable sampling areas are identified using a model developed for vegetation monitoring that identifies areas <1000 m from an active road or trail and on slopes <30 degrees (see Chapter 4 of the Klamath Network Vital signs Monitoring Plan);
2. Ponds and lakes that intersect the suitable sampling area and are <25 m in maximum depth are identified as suitable ponds-lakes for the selection of sampling sites;
3. Subjectively selected judgment sampling sites are identified and removed from the list of all suitable ponds-lakes;
4. Index sampling sites are then randomly selected and removed from the list of suitable ponds-lakes;
5. Survey sampling sites are then randomly selected from the list of suitable ponds-lakes;
6. The process of selecting survey sites is performed nine more times until enough ponds and lakes are selected to populate 10 time steps (i.e., Time 1 = 1st sampling year; Time 2 = 2nd sampling year, etc.) in each park;
7. Note that because the selection of survey sites for time steps is performed using a select and replace process, there is a chance that one or more ponds-lakes will be selected more than once as a survey site;
8. All judgment, index, and survey sites are then symbolized and added to respective park maps.

Two sites, one lake and one freshwater lagoon, have been selected as judgment sampling sites. The rationale and justification for selecting these sites are:

1. Lake Helen (Lassen NP): this site was selected because it is relatively unbuffered and is subject to potential impacts from a parking lot, road corridor, and visitor day use;
2. Freshwater Lagoon (Redwood NP): this site was selected because it is the largest lagoon in the park and is considered impaired due to the presence of exotic vegetation and introduced fish.

4.3. Sampling Frequency, Replication, and Timing of Sampling

Sampling frequency, replication, and timing will vary by sampling year, ecosystem, park, and sampling site type (see Table 5):

1. In year 1, wadeable cold-stream sites will be sampled at Redwood NP, Crater Lake NP, and Oregon Caves NM;
2. In year 2, wadeable cold-streams will be sampled at Whiskeytown NRA, Lassen NP, and Oregon Caves NM;
3. In year 3, ponds, lakes, and one freshwater coastal lagoon will be sampled at Crater Lake NP, Lassen NP, and Redwood NP;
4. Judgment and index sites will be sampled annually, once during the summer field season. In the year that a judgment or index site is scheduled to be sampled in a park (e.g., year 1: Redwood NP, wadeable cold-streams, year 3: Crater Lake NP, ponds-lakes; see Table 4), a suite of physical, chemical, and biological parameters will be measured and sampled at all sampling sites. In off years (i.e., years when an ecosystem in a particular park is not scheduled to be sampled by the seasonal crews, such as years 2 and 3: Redwood NP, wadeable cold-streams, years 1 and 2: Crater Lake NP, ponds-lakes; see Table 4) only a limited number of core parameters (i.e., water temperature, specific conductance, dissolved oxygen, pH, flow-discharge, turbidity, water-level, and macroinvertebrates) will be measured and/or sampled.
5. Survey sites will be sampled once during the summer season, no more frequently than every three years. In the year that a survey site is scheduled to be sampled at a park (e.g., year 1: Redwood NP, wadeable cold-streams, year 3: Crater Lake NP, ponds-lakes; see Table 4), a suite of physical, chemical, and biological parameters will be measured at all sampling sites. Core parameters will not be measured in off years at survey sampling sites.
6. Note that because survey sites to be sampled in any given year will always be selected from a pool of all suitable sites/ecosystem, some, perhaps many, survey sites will not be consistently revisited (i.e., every three years), or revisited at all.

Recommended Number and Location of Sampling Sites

There will be 28-30 sites/ecosystem/park sampled during each 3-year sampling interval, except for one freshwater coastal lagoon judgment sampling site at Redwood NP and three stream judgment sampling sites at Oregon Caves NM (see Table 4). Judgment sampling sites/park range from 1-4, index sampling sites/park range from 12-14, and survey sampling sites/park range from 14-15 (see Table 4). The number of randomly selected index and survey sites sampled over three years will ensure that the standard errors of the parameter estimates will be relatively small, allowing for better inference at the park-level with respect to the status and trends of the sampled ecosystems (A. Merton, pers. comm.).

A total of 119, 100-m wadeable cold-stream sampling sites will be sampled during years 1 and 2 of the first 3-year monitoring period (see Table 4), including 14 judgment sites (12%), 48 index sites (40%), and 57 survey sites (48%). A total of 58 ponds and lakes will be sampled in year 3 of the first 3-year monitoring period (see Table 4), including two judgment sites (4%), 28 index sites (48%), and 28 survey sites (48%).

4.4. Parameters to be Sampled

The parameters to be sampled as part of the Klamath Network integrated freshwater quality and aquatic community monitoring plan can be separated into five basic categories: (1) core parameters, (2) physical habitat characteristics of wadeable cold-stream sampling sites, (3) physical habitat characteristics of pond-lake sampling sites, (4) water chemistry, and (5) biological communities (Table 5).

Core Water Quality Parameters
The core parameters (Table 5) represent a minimum set of water quality attributes that will be measured as part of all NPS water quality monitoring plans. As such, these attributes contribute some measure of consistency and comparability of water quality conditions among multiple monitoring programs (NPS 2002). Core parameters will be measured at all sampling sites (judgment, index, and survey) the year in which each ecosystem is scheduled to be sampled at a park (e.g., year 1: Redwood NP, wadeable cold-streams; year 3: Crater Lake NP, ponds-lakes; see Table 4). In off years (e.g., years 2 and 3: Redwood NP, wadeable cold-streams; years 1 and 2: Crater Lake NP, ponds-lakes; see Table 4), core parameters only will be measured at judgment and index sites. Core water quality parameters can be analyzed individually to allow risk assessment and reporting about specific pollutants or environmental changes or can be integrated with other chemical and biological parameters to assess aquatic ecosystem integrity (see Figure 2).

Physical Habitat Characteristics
The physical habitat characteristics of wadeable cold-streams and ponds-lakes (Table 5) are important components of aquatic resource monitoring because these characteristics contribute to and help describe the context or template for ecosystem function and condition (Southwood 1977; Warren 1979; Frissell et al. 1986; Larson et al. 1994, 1999). Many of the characteristics can be determined using available park GIS layers and can be recorded prior to the beginning of each field season. Other characteristics will require measurement in the field. Characteristics marked with a (+) in Table 5 do not necessarily need to be recorded upon subsequent visits to judgment and index sampling sites or survey sampling sites that may be randomly selected for a revisit. Physical characteristics that require re-measurement are not re-measured in off years.

Water Chemistry Parameters
Analysis of the chemical characteristics of water is fundamental to the effective monitoring of the water quality of aquatic resources. Water chemistry parameters (Table 5) are good indicators of the trophic state (e.g., oligotrophic, mesotrophic, eutrophic) or productivity of aquatic ecosystems, the natural variability of conditions within and among trophic states, the capacity of ecosystems to support biotic communities, and potential changes in ecosystem status and trends. Samples for water chemistry analysis should be collected at all sampling sites the year in which each ecosystem is scheduled to be sampled at a park (e.g., year 1: Redwood NP, wadeable cold-streams; year 3: Crater Lake NP, ponds-lakes; see Table 4). Water chemistry samples are not collected in off years

(e.g., years 2 and 3: Redwood NP, wadeable cold-streams; years 1 and 2: Crater Lake NP, ponds-lakes; see Table 4).

Biological Community Parameters

Biotic communities are important components of healthy aquatic ecosystems that are determined by and sensitive to the conditions of the habitats within which they reside (Loeb 1994). Biological community parameters (Table 5) such as the chlorophyll concentration of phytoplankton and periphyton and the composition of benthic macroinvertebrate assemblages can be quite sensitive indicators of change within aquatic ecosystems. Chlorophyll concentration can be affected by an increase or decrease of nutrient input into a system and benthic macroinvertebrates can be good indicators of habitat degradation. Zooplankton, which are important members of pond-lake communities, provide an interesting baseline for documenting the inherent variability of aquatic communities among lentic ecosystems (Hutchinson 1961; Larson et al. 2002). Documenting the presence or absence of amphibian and fish species in aquatic ecosystems also can be useful for determining ecosystem health, although their contribution is more variable and less diagnostic (Moyle 1994) than assessments based on chlorophyll concentration and benthic macroinvertebrate assemblages. Collection of biotic samples and the assessment of biotic communities should be completed at all sampling sites the year in which each ecosystem is scheduled to be sampled at a park (e.g., year 1: Redwood NP, wadeable cold-streams; year 3: Crater Lake NP, ponds-lakes; see Table 4). Biotic sample collection and community assessment are not performed in off years (e.g., years 2 and 3: Redwood NP, wadeable cold-streams; years 1 and 2: Crater Lake NP, ponds-lakes; see Table 4).

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Table 5. Monitoring Parameters in each of Five Basic Parameter Categories. APHA = American Public Health Association. 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition. Washington, D.C. WS = wadeable streams; P-L = ponds and lakes. Characteristics marked with (+) need not be re-measured upon revisits to sampling sites.

Category	Parameter	Activity	Method
Core (WS and P-L)	Temperature	Measure	YSI85-Field
	Specific Conductance	Measure	YSI85-Field
	Dissolved Oxygen	Measure	YSI85-Field
	pH	Measure	Hach pH meter-Field
	Flow/Discharge (WS)	Channel Cross-section Assessment	Measure-Field
	Water-level (P-L)	Bench Mark Assessment	Measure-Field
	Turbidity (P-L)	Determine	Hach turbidimeter-Field
	Water Clarity (P-L)	Determine	Secchi Disk
Physical Habitat Characteristics (WS)	Site Location	Determine Coordinates +	GIS and GPS-Field
	Thalweg Profile	Maximum Depth & Wetted Width	Measure-Field
		Habitat & Pool Forming Features +	Classify-Field
		Presence of Backwaters, Side Channels, & Soft Substrates +	Observe & Record-Field
	Channel & Riparian Characterization	Channel Cross-Section Dimensions	Measure-Field
		Bank Height	Measure-Field
		Slope (Gradient) and Compass Bearing +	Measure-Field
		Riparian Canopy Density	Measure-Field
		Presence and Proximity of Human Disturbance	Observe & Record-Field
Physical Habitat Characteristics (P-L, except * = WS and P-L)	Site Location	Determine Coordinates +	GIS and GPS-Field
	Elevation	Determine or Measure +	GIS/Altimeter
	Surface Area	Determine or Measure +	GIS/Polar Planimetry
	Perimeter	Determine or Measure +	GIS/Measure
	Inlets & Outlets	Presence and Location +	Observe & Record-Field
	Basin Aspect	Determine +	GIS or Compass/GPS
	Basin Watershed Area*	Determine +	GIS
	Basin Geologic Composition*	Determine +	GIS
	Basin Origin	Determine +	Classify-Field
	Vegetation Zone*	Determine +	GIS
	Maximum Depth	Determine	Measure (Depth-finder)

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Table 5. Monitoring Parameters in each of Five Basic Parameter Categories. APHA = American Public Health Association. 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition. Washington, D.C. WS = wadeable streams; P-L = ponds and lakes. Characteristics marked with (+) need not be re-measured upon revisits to sampling sites. (continued).

Category	Parameter	Activity	Method
Water Chemistry (WS and P-L)	Alkalinity	Unfiltered Water Sample	Lab-APHA 2320
	Cations (Na, K, Ca, Mg)	Filtered Water Sample	Lab-APHA 3111B,D
	Anion (Cl)	Filtered Water Sample	Lab-APHA 4110B
	Total Nitrogen	Filtered Water Sample	Lab-APHA 4500-NO3/NO2
	Ammonia	Filtered Water Sample	Lab-APHA 4500-NH3
	Nitrate/Nitrite	Filtered Water Sample	Lab-APHA 4500-SiO2
	Silica	Filtered Water Sample	Lab-APHA 4500-P B
	Total Phosphorus	Filtered Water Sample	Lab-APHA 2540 D
	Total Suspended Solids	Unfiltered Water Sample	Lab-APHA 5310B
	Dissolved Organic Carbon	Filtered Water Sample	Lab-APHA Part 3000
	Metals (WHIS only)	Samples of Fine-Grained Surficial Sediments	
Biological Community (Lentic & Lotic)	Periphyton (WS)	Dry Weight-Biomass	Lab-Oven and Muffle
	Chlorophyll (P-L)	Concentration	Lab-fluorometer
	Fecal Indicator Bacteria (ORCA & WHIS)	Collect Water Samples	Laboratory Analysis
	Zooplankton (P-L)	Vertical/Horizontal Tows	Lab-ID and Counts
	Benthic Macroinvertebrates	Benthic Samples	Lab-ID and Counts
	Amphibians	Presence/Absence Surveys	Snorkel (WS); VES (P-L)
	Fish	Presence/Absence Surveys	Snorkel (WS); Gill Nets (P-L)

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4.5. Examples of Potential Levels of Detected Change for Each Park

Streams, ponds, and lakes in Klamath Network parks have been previously sampled, although overall sampling has not been coordinated and systematic. The data derived from past sampling efforts, however, can be useful for identifying relative expected values for various water quality parameters that can be used as a starting point for estimating potential deviance beyond natural variation. The following data are provided as examples of data collected and potential expected values for various water quality parameters in Klamath Network lotic and lentic ecosystems.

Crater Lake NP
Up to 31 wadeable cold-streams and tributaries in Crater Lake NP were sampled between 1967 and 1968 (Frank and Harris 1969) for 11 water quality parameters:

Parameter	n	Mean	SE	Minimum	Maximum
Bicarbonate (mg/L)	45	26.3	1.18	13.0	44.0
Calcium (mg/L)	45	1.22	0.19	1.6	6.8
Chlorine (mg/L)	22	0.59	0.13	0	2.5
Iron (mg/L)	7	0.18	0.12	0.01	0.89
Magnesium (mg/L)	45	1.22	0.09	0.2	2.6
Nitrate (mg/L)	8	0.025	0.025	0	0.2
pH (units)	45	7.2	0.04	6.7	7.8
Potassium (mg/L)	7	1.86	0.10	1.5	2.3
Sodium (mg/L)	45	3.15	0.13	1.6	6.2
Silica (mg/L)	31	32.3	1.06	18.0	42.0
Sulfite (mg/L)	8	0.8	0.56	0	4.6

Samples for 11 water quality parameters were collected in 1993 from ponds in the Whitehorse Ponds complex as part of a study of the physical, chemical, and biological characteristics of ponds located on Whitehorse Bluff (Salinas et al. 1994):

Parameter	n	Mean	SE	Minimum	Maximum
Alkalinity HCO3-C (mg/L)	4	0.63	0.068	0.51	0.81
Calcium (mg/L)	4	0.33	0.077	0.16	0.46
Chlorine (mg/L)	4	0.26	0.102	0.07	0.55
Conductance (µMHOS/cm)	8	8.77	1.39	4.2	16.6
Dissolved Oxygen (mg/L)	7	5.62	0.36	4.56	6.69
Magnesium (mg/L)	4	0.08	0.012	0.058	0.11
Nitrate/Nitrite (mg/L)	3	0.003	0.0003	0.002	0.003
pH (units)	16	5.6	0.1	5.2	6.2
Phosphorus (Total; mg/L)	4	0.028	0.009	0.008	0.045
Potassium (mg/L)	4	0.30	0.09	0.11	0.53
Sodium (mg/L)	4	0.45	0.13	0.14	0.77

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Lassen NP

Samples for three water quality parameters were collected in 2005 from five streams (Currens et al. 2006):

Parameter	n	Mean	SE	Minimum	Maximum
Alkalinity, as CaCO3 (mg/L)	27	32.6	3.5	11.0	66.0
pH (units)	19	7.4	0.1	6.7	8.5
Specific Conductance (µMHOS/cm)	4	85.2	20.9	40.0	135.0

Samples for three water quality parameters were collected in 2005 from 23 ponds-lakes (Currens et al. 2006):

Parameter	n	Mean	SE	Minimum	Maximum
Alkalinity, as CaCO3 (mg/L)	95	11.7	1.33	ND	48.0
pH (units)	49	7.1	0.1	5.8	9.6
Specific Conductance (µMHOS/cm)	34	17.6	4.48	ND	97.0

Oregon Caves NM

Samples for eight water quality parameters were collected in 2005 from three sections of Cave Creek (Currens et al. 2006):

Parameter	n	Mean	SE	Minimum	Maximum
Alkalinity, as CaCO3 (mg/L)	22	102.7	3.91	63.0	120.0
Bicarbonate CaCO3 (mg/L)	10	117.0	1.53	110.0	120.0
Carbonate CaCO3 (mg/L)	11	0.6	0.17	ND	1.1
Chloride (mg/L)	9	1.17	0.03	1.1	1.3
Conductivity (µMHOS/cm)	4	182.5	18.0	130.0	210.0
Hydroxide CaCO3 (mg/L)	8	ND	ND	ND	ND
Nitrate (mg/L)	9	ND	ND	ND	ND
pH (units)	15	7.7	0.10	6.4	8.0

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Redwood NP

These summarized water quality data are from the only comprehensive water quality investigation conducted in the Redwood Creek and Mill Creek drainage basins (David Anderson, pers. comm.; Bradford and Iwatsubo 1978). The investigation was conducted September 1973-September 1975 to determine existing chemical water quality conditions of streams in these drainages.

Redwood Creek Drainage Basin (n = number of samples; SD = standard deviation):

Parameter	Units	n	Mean	SD	Minimum	Maximum
Silica	mg/L	182	6.44	1.07	4	14
Aluminum	µg/L	161	36	42	0	280
Iron	µg/L	168	72	97	10	670
Calcium	mg/L	182	7.87	6.81	1.9	40
Magnesium	mg/L	182	1.55	0.77	0.3	4.3
Sodium	mg/L	186	4.47	1.15	1.9	7.2
Potassium	mg/L	182	0.7	0.25	0.3	2
Bicarbonate	mg/L	177	30.5	19.2	8	104
Carbonate	mg/L	118	0.009	0.92	0	1
Alkalinity, as CaCO3	mg/L	1187	29.9	21	3	111
Sulfate	mg/L	183	4.68	4.65	0.9	29
Chloride	mg/L	189	4.82	1.53	1.6	11
Fluoride	mg/L	63	0.13	0.21	0	1
Nitrite plus Nitrate	mg/L	170	0.09	0.21	0	2.2
Ammonia	mg/L	108	0.02	0.03	0	0.26
Nitrogen, organic	mg/L	108	0.29	0.72	0	3.3
Nitrogen, Kjeldahl	mg/L	182	0.26	0.57	0	3.3
Phosphorus, total dissolved	mg/L	182	0.03	0.08	0	1
Orthophosphorus, dissolved	mg/L	80	0.014	0.023	0	0.17
Solids, dissolved	mg/L	168	46.1	20.9	25	139
Hardness, as CaCO3	mg/L	188	27	20.3	8	120
Specific Conductance	µmho/cm	2494	80.2	50.1	17	295
pH	units	1557	7.1	0.5	4.7	8.9
Temperature	^{o}C	2398	10.8	3.8	4.5	25
Dissolved Oxygen	mg/L	1241	10.3	1.25	5.9	13
Dissolved Organic Carbon	mg/L	148	3.4	2.1	0.1	11

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Mill Creek Drainage Basin (n = number of samples; SD = standard deviation):

Parameter	Units	n	Mean	SD	Minimum	Maximum
Silica	mg/L	46	7.03	1.03	4.9	8.9
Aluminum	µg/L	46	46	61	0	370
Iron	µg/L	45	54	66	10	470
Calcium	mg/L	46	4.03	1.5	1.7	7.7
Magnesium	mg/L	46	1.46	0.62	0.1	3
Sodium	mg/L	46	3.27	0.7	2.0	4.7
Potassium	mg/L	46	0.6	0.21	0.3	1.3
Bicarbonate	mg/L	46	17.5	6.8	8	32
Carbonate	mg/L	17	0.0	0.0	0.0	0.0
Alkalinity, as CaCO3	mg/L	188	17.5	6.0	6	35
Sulfate	mg/L	46	1.98	0.84	0.9	5
Chloride	mg/L	43	3.82	0.91	1.8	5.7
Fluoride	mg/L	33	0.05	0.07	0.0	0.2
Nitrite plus Nitrate	mg/L	46	0.38	0.68	0.0	3.9
Ammonia	mg/L	13	0.017	0.035	0.0	0.13
Nitrogen, organic	mg/L	13	0.74	1.09	0.03	2.8
Nitrogen, Kjeldahl	mg/L	45	0.44	0.63	0.02	2.8
Phosphorus, total dissolved	mg/L	45	0.01	0.01	0.0	0.04
Orthophosphorus, dissolved	mg/L	36	0.014	0.009	0.0	0.04
Solids, dissolved	mg/L	46	32.7	7.2	21	49
Hardness, as CaCO3	mg/L	28	16.1	5.1	8	28
Specific Conductance	µmho/cm	88	50.2	13.3	26	88
pH	units	196	6.9	0.4	5.9	7.7
Temperature	^{o}C	287	13.1	4.4	5	23
Dissolved Oxygen	mg/L	188	9.59	1.24	6.3	12.1
Dissolved Organic Carbon	mg/L	44	3.55	2.06	0.6	9.2

Whiskeytown NRA

Continuous sampling of six water quality parameters was conducted in Paige Boulder Creek as part of a watershed restoration project (Rasmussen 2002). The ranges below are for the period June-September 2000-2002:

Parameter	Median	Minimum	Maximum
Discharge (CFS)	1.4 – 4.7	1.0 – 2.7	1.7 – 25.6
Dissolved Oxygen (mg/L)	8.0 – 9.5	6.3 – 8.4	9.9 – 11.6
pH (units)	7.3 – 7.6	6.9 – 7.4	7.9 – 8.3
Specific Conductance (µS/cm)	57 - 98	45 - 76	63 - 142
Turbidity (NTU)	0 – 0.3	0 – 0.1	0.7 – 24.4
Water Temperature (C)	17.3 – 22.6	12.6 – 18.8	21.1 – 28.0

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

Water samples were collected for the assessment of metals contamination as part of a cooperative study conducted by the USGS, University of Montana, and the National Park Service (May et al. 2005). The study was designed to determine, in part, the release and transport of metals from mining wastes within the French Fire burned area, and the data below summarizes some of the preliminary results for 2004 samples collected by the USGS, except Hg collected by University of Montana in 2003 (As = Arsenic; Cd = Cadmium; Cr = Chromium; Cu = Copper; Hg = Mercury; Ni – Nickel; Pb = Lead; Se = Selenium; Zn = Zinc):

Sample Site	As (0.1)*	Cd (0.02)*	Cr (0.4)*	Cu (0.2)*	Hg (2.5)*	Ni (0.03)*	Pb (0.04)*	Se (0.2)*	Zn (0.3)*
1	0.063	<0.02	<0.4	0.523	4.8	0.115	<0.04	0.015	0.842
2	NC	NC	NC	NC	4.6	NC	<0.04	NC	NC
3	0.679	<0.02	<0.4	0.483	3.0	0.326	<0.04	0.277	1.31
4	7.845	<0.02	<0.4	0.552	<2.5	0.272	<0.04	0.335	0.787
5	NC	NC	NC	NC	3.0	NC	<0.04	NC	NC
6	21.992	<0.02	<0.4	0.636	7.4	0.45	<0.04	0.486	2.017
7	3.348	<0.02	<0.4	0.717	6.8	0.359	<0.04	0.183	0.679
8	NC	NC	NC	NC	4.8	NC	<0.04	NC	NC
9	NC	NC	NC	NC	9.2	NC	<0.04	NC	NC

* PQL = Practical Quantification Limit
NC = Not Collected

Chapter 5: Sampling Protocols

5.1. Field Season Preparations

Standard Operating Procedures (SOPs) 1-14 (see subsection 5.3) describe established methods for the measurement and collection of samples that will help elucidate freshwater quality and aquatic community characteristics of the ecosystems being monitored. The protocol and associated SOPs of the monitoring plan should be reviewed at the beginning of each field season by all individuals participating in the monitoring program.

Prior to the beginning of the field season, typically mid-June, the Network Coordinator and Aquatic Ecologist will complete the process of hiring seasonal field technicians (1 crew leader and 3 crew members). The seasonal field technicians will be under the supervision of the Aquatic Ecologist; however, when in the field, crew members will be directly supervised by the crew leader. The Network Aquatic Ecologist also will be responsible for inventorying and gathering all necessary gear required for successful sampling of all monitoring sites (including vehicles, camping gear, and measurement and sampling tools and instruments), the completion of all compliance procedures and documentation, and the acquisition of any necessary permits.

Seasonal crew members will be trained during the first week of the field season. However, prior to arrival at the Klamath Network office, all seasonal hires will need to complete their basic First Aid and CPR certification. In addition, crew members should be skilled and/or certified in swimming, backpacking, and orienteering skills. Training during the first week will include (1) driver safety, (2) review of safe practices and procedures in front- and back-country locations (excellent guidance for personnel training and safety is available in the SFAN "Freshwater Quality Monitoring Protocol," version 2.01, SOP 2: Personnel Training and Safety, available at: http://www1.nature.nps.gov/im/units/sfan/vital_signs/water_quality.cfm), (3) review of water and boating safety, and (4) review of protocol SOPs. At this time, training in sampling techniques and the use and calibration of sampling tools and instruments (e.g., an electronic hand-held multi-parameter meter and portable turbidimeter) will be completed. This training will be supervised by the Network Aquatic Ecologist.

5.2. Sequence of Field Season Events

A. Field crew members will be trained; all required instruments, equipment, and gear assembled; and all field instruments calibrated during the first week of the field season (mid-June). The four crew members will be separated into two teams of two members.
B. Sampling will begin the second week of the field season. The field-crews will travel to each park together. Field crews will complete the sampling of all monitoring sites

in one park before traveling to and beginning sampling at the next park. This process will be repeated until all parks are sampled. Sampling will proceed as follows (see Table 4):

1) Year 1: Redwood NP, Oregon Caves NM, Crater Lake NP;
2) Year 2: Whiskeytown NRA, Oregon Caves NM, Lassen NP;
3) Year 3: Redwood NP, Lassen NP, Crater Lake NP.

C. At each sampling site, crew members will (1) sample core parameters and measure and assess physical habitat characteristics, and (2) collect and field process, when required, water chemistry and biological samples.

D. At the end of each day of sampling, crew members will transport water chemistry and biological samples from the field to an in-park holding facility for maintaining samples according to proper sample handling and holding procedures. Data entry also will be completed at this time.

E. At the conclusion of sampling at each park, and before traveling to the next park, crew members will prepare water chemistry and biological samples for shipment to contract laboratories for processing. Park staff will assist crew members with, and in certain situations be responsible for, the preparation and shipment of samples.

F. At the conclusion of the field season, crew members will return to the Klamath Network office, where they will (1) inventory, clean, and store all sampling instruments, equipment, and gear; (2) complete final data entry into the monitoring program database; and (3) QA/QC all data entry.

G. During the field season, the parks will provide technical and logistical support to the field crews and suitable facilities for the storage of field instruments, equipment, gear, and collected samples.

5.3. Measurement Details

The SOPs of the monitoring plan are designed to provide clear and detailed guidance for every aspect of the Klamath Network integrated freshwater quality and aquatic community monitoring program. Because the water quality and aquatic community monitoring protocol is under development at this time and an Aquatic Ecologist has yet to be hired, these draft SOPs are provided to summarize our progress in planning the monitoring program as of September 2007. Overall guidance for the development of monitoring program protocols and SOPs is available in the NPS-WRD document: Part B lite (Just the Basics) QA/QC Review Checklist for Aquatic Vital Sign Monitoring Protocols and SOPs (Irwin 2006), available at: http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/PartBLite.pdf.

The SOPs for this plan also will be adapted from six pre-existing protocols that have been field tested and implemented:

- **EMAP:** Environmental Monitoring and Assessment Program - Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. EPA,

unpublished draft (Peck et al. 2001), available at: http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/fomws.html.
    - This manual was developed as part of the USEPA Environmental Monitoring and Assessment Program. The manual's SOPs were tested during five years (1993-1997) of pilot and demonstration projects.
- **SFAN:** Freshwater Quality Monitoring Protocol Version 2.01 – San Francisco Bay Area Network (Cooprider 2005), available at: http://www1.nature.nps.gov/im/units/sfan/vital_signs/water_quality.cfm.
    - This protocol was developed as part of the NPS Inventory and Monitoring Program to organize and guide the long-term monitoring of water quality of SFAN freshwater resources.
- **USGS-NCCN**: Sampling Protocol for Monitoring Abiotic and Biotic Characteristics of Mountain Ponds and Lakes, 2005, US Geological Survey Techniques and Methods 2-A2 (Hoffman et al. 2005), available at: http://pubs.usgs.gov/tm/2005/tm2a2.
    - This protocol was developed by the USGS in cooperation with the NPS North Coast and Cascades Network for use in their mountain ponds and lakes long-term water quality monitoring program. A pilot implementation of the protocol began in the summer of 2005. Although this protocol was written specifically for sampling mountain ponds and lakes, the methods described for the collection of various types of lentic samples also are applicable to the collection of samples from freshwater lagoons.
- **Random X Survey Technique** (Bury et al. 2003; available as a PDF document).
    - This protocol describes methods for surveying and examining the species richness and relative abundances of amphibians in permanent headwater stream systems. It builds on prior stream amphibian sampling methods such as Bury and Corn (1991), and Welsh and Hodgson (1997).
- **Protocol for Determining Bull Trout Presence** (Peterson et al. 2002).
    - This protocol describes snorkeling methods for determining the presence of fish in streams. It also provides guidance for electrofishing.
- **Ground-based Photographic Monitoring** (Hall 2001).
    - This protocol provides guidance for repeat photo-documentation of sampling sites.

Protocol Standard Operating Procedures

SOP 1: Revising the Protocol
SOP 2: Personnel Training and Safety
SOP 3: Equipment and Field Preparations
SOP 4: Quality Assurance Project Plan (QAPP)
SOP 5: Field Methods for the Measurement of Core Parameters
SOP 6: Field Methods for the Measurement of Physical Characteristics
SOP 7: Field Methods for the Collection of Water Quality Samples
SOP 8: Field Methods for the Collection of Biological Samples
SOP 9: Field Methods for the Assessment of Amphibians and Fish
SOP 10: Field Methods for Sampling Fecal Indicator Bacteria
SOP 11: Field and Laboratory Methods for Sediment

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

SOP 12: Data Analysis
SOP 13: Data Reporting
SOP 14: Site Selection and Documentation

SOP 1: Revising the Protocol: (to be adapted from SOP 1 of the SFAN Freshwater Quality Monitoring Protocol).

This SOP will provide guidance for revision of the protocol and its SOPs, especially after the initial years of protocol implementation. The protocol and the field methods used to measure, assess, and sample the characteristics of monitoring sites should be reviewed often (e.g., at least every two years) so that program managers can assess the effectiveness of the methods being used, the quality of the data being collected relative to program objectives, and revise the protocol to meet revised program objectives.

SOP 2: Personnel Training and Safety: (to be adapted from SOP 2 of the SFAN Freshwater Quality Monitoring Protocol).

The safety of all monitoring program personnel is of the utmost importance and the top priority of the program. This SOP will stress the importance of teamwork in the maintenance of safety, especially when working in relatively remote back-country locations, and will include sections on potential safety hazards, procedures for safety preparation, personnel safety forms, and a checklist of standard safety equipment.

SOP 3: Equipment and Field Preparation: (to be adapted from SOP 3 of the SFAN Freshwater Quality Monitoring Protocol).

This SOP will primarily provide guidance for the calibration, inspection, maintenance, and use of a multi-parameter meter for the measurement of pH, specific conductance, dissolved oxygen, water temperature and flow, and use of a handheld portable turbidimeter.

SOP 4: Quality Assurance Project Plan (QAPP): Following NPS guidance (Irwin 2004), this SOP will include: (1) Quality Control objectives for measurement certainty and detection limits such as method detection limit (MDL) and practical quantitative limit (PQL), (2) Quality Control objectives for measurement precision, (3) Quality Control objectives for measurement of systematic error (bias as percent recovery), (4) Quality Control objectives for data completeness (including adequacy of planned sample sizes and statistical power), and (5) Quality Control objectives for blank controls for lab measurements.

SOP 5: Field Methods for the Measurement of Core Parameters: (to be adapted from the following protocols and SOPs: (1) wadeable cold-streams: SFAN SOP 5 and 9; ponds-lakes: USGS-NCCN SOP 2, 3, and 5. Additional guidance available from NPS-WRD (2002), Recommendations for core water quality parameters and other key elements of the NPS Vital Signs Program, Water Quality Monitoring Component. 19 pp.).

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

This SOP will provide guidance for the measurement of water temperature, specific conductance, dissolved oxygen, flow/discharge (wadeable cold-streams), and water-level (ponds-lakes).

SOP 6: Field Methods for the Measurement of Physical Characteristics: (to be adapted from EMAP Section 7 for wadeable cold-streams, and USGS-NCCN SOPs 1, 2, and 4 for ponds-lakes).

This SOP will provide guidance for documenting and measuring the physical characteristics of sampling sites. The parameters documented and measured (see Table 5) will provide data helpful in determining baseline conditions and potential change relative to these conditions.

SOP 7: Field Methods for the Measurement of Water Quality Samples: (to be adapted from SFAN SOP 7 for wadeable cold-streams, and USGS-NCCN SOP 5 for ponds-lakes).

This SOP will provide guidance for the collection, labeling, handling, and storage of water samples. These samples will be analyzed for a suite of water quality parameters (see Table 5) useful for determining baseline conditions, determining status, tracking trend, and identifying potential change in water quality beyond natural variation.

SOP 8: Field Methods for the Collection of Biological Samples: (to be adapted from EMAP Sections 8 and 11 for wadeable cold-streams, and USGS-NCCN SOPs 6, 7, and 8 for ponds-lakes).

This SOP will provide guidance for collecting, labeling, handling, and storing the following samples benthic macroinvertebrate, chlorophyll, periphyton, and zooplankton samples (see Table 6). These samples, when processed and analyzed, will be helpful for identifying multiple metrics related to invertebrate assemblages in wadeable cold streams and ponds-lakes, and will be useful for determining baseline conditions, determining status, tracking trend, and identifying potential change in invertebrate assemblages beyond natural variation.

SOP 9: Field Methods for the Assessment of Amphibians and Fish: (to be adapted from Random X and Protocol for Determining Bull Trout Presence for wadeable cold-streams, and USGS-NCCN SOPs 9 and 12 for ponds-lakes).

This SOP will provide guidance for surveying and assessing the composition and structure of amphibian and fish assemblages (see Table 5). These surveys will be useful for determining baseline conditions, determining status, tracking trend, and identifying potential change in amphibian and fish assemblages beyond natural variation.

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

SOP 10: Field Methods for Sampling Fecal Indicator Bacteria: (to be adapted from SFAN SOP 6).

This SOP will provide guidance for the sterile field collection of bacterial samples and their proper labeling and storage.

SOP 11: Field and Laboratory Methods for Sediment: (to be adapted from SFAN SOP 8).

This SOP will provide guidance for the preparation of sample bottles and the field collection of samples. Use of a portable turbidimeter will be discussed in SOP 3.

SOP 12: Data Analysis: (to be adapted in part from SFAN SOP 10).

This SOP will provide details for analyzing data generated by the monitoring program. Analysis options will include descriptive statistics, parametric and nonparametric statistics to describe status, calculation of proportions of streams and ponds-lakes affected for water quality assessment, trend analysis, development of diversity indices for aquatic community analysis, multivariate analysis of ecosystem characteristics, and the assessment of amphibian species and assemblages.

SOP 13: Data Reporting: (to be adapted in part from SFAN SOP 11).

This SOP will provide details on reporting intervals, as well as report content and format.

SOP 14: Site Selection and Documentation: (the photo-documentation part of this SOP will be adapted from Hall 2001).

This SOP will discuss the process of selecting monitoring sites and sampling locations within sites, naming conventions for sites, and photographically documenting physical and habitat characteristics of monitoring sites.

5.4. Field Measurement and Laboratory Analysis

Physical, chemical, and biological parameters will either be measured and processed in the field or shipped to contracting laboratories for processing and analysis. Table 5 summarizes the general activities and methods by which these parameters will be assessed. Sample processing and analysis by contract laboratories will meet NPS Quality Assurance Project Plan (QAPP) requirements.

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

5.5. End-of-Season Procedures

The last week of the field season will be spent at Network headquarters in Ashland, Oregon. Crew members will copy and archive all field data sheets and enter data into the monitoring program database. Data entry will be quality assured during this period by the crew leader and one crew member. All gear, equipment, and instruments will be cleaned, inventoried, and stored. The Network Aquatic Ecologist will conduct end-of-season debriefings of crew members prior to the end of their seasonal appointments.

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

Chapter 6: Data Management

6.1. Data Management

The clear, concise, and consistent recording, analysis, and reporting of data is essential to the success of the Klamath Network integrated freshwater quality and aquatic community monitoring plan and will be a top priority for all personnel involved in the monitoring program. During each phase of the monitoring effort, from parameter assessment, sample collection, and sample processing to data entry, analysis, and reporting, standard quality assurance and quality control checks will be used to ensure the accuracy and completeness of the monitoring program. Responsibilities for each person involved in the project will be outlined prior to implementing fieldwork. Guidance for data management and analysis (in general, and in the field and laboratory) are available from the Klamath Network Data Management Plan, Data Management Guideline Documents, Monitoring Plan, and Water Quality and Aquatic Community Protocol. The standard operating procedures available in the protocol provide the data management details for each project. These SOPs will be developed from the following guidance documents:

1. Klamath Network Data Management Plan (Appendix J): http://www1.nature.nps.gov/im/units/klmn/MON_Phase_III.cfm
2. NPS Data Management website: http://science.nature.nps.gov/im/datamgmt/index.cfm
3. Data collection and management in the field and laboratory: Sampling Protocol for Monitoring Abiotic and Biotic Characteristics of Mountain Ponds and Lakes, 2005, US Geological Survey Techniques and Methods 2-A2, SOP 13.
4. EPA Guidance for Quality Assurance Project Plans (1998): http://www.epa.gov/r10earth/offices/oea/epaqag5.pdf; and
5. SFAN "Freshwater Quality Monitoring Protocol," version 2.01, SOP4: Quality Assurance Project Plan (QAPP), available at: http://www1.nature.nps.gov/im/units/sfan/vital_signs/water_quality.cfm.

6.2. Database Design

The water quality component of the Natural Resource Challenge (NRC) requires that all NPS networks archive any physical, chemical, and biological water quality data collected with NRC water quality funds in the NPS STORET (STOrage and RETrieval) databases. To assist in this process, networks have the opportunity to make use of a relational database patterned after the Natural Resource Database Template and developed by the Water Resources Division (WRD) called NPSTORET; or they can utilize any of the numerous databases already available as long as they can export that data into a format that meets the STORET Electronic Data Deliverable (NPSEDD) specifications. After analyzing the potential available databases and examining the utility of the NPSTORET

Database, the Klamath Network has opted to use the NPSTORET database for all their aquatic and water quality monitoring projects.

6.3. Data Entry and Data Sheet Archival

The Klamath Network, when possible, will make use of tablet PCs to collect data associated with the water quality and aquatic community protocols. It is the responsibility of the Field-Crew Leader and Project Manager to adequately train field-crews in data collection and management methodologies outlined in each protocol. Since these protocols are long-term commitments and crew turnover is expected, a training manual is recommended. A log should be kept outlining the training sessions each crew member attends, and logs should be transferred to the Data Manager at the end of each field season.

While the Network will make every attempt to enter data electronically in the field, we recognize there are instances when this will not be possible. Field-crews should always have hardcopy field forms available when going to monitoring sites. If data is entered onto hardcopy forms, they should be entered into the database as soon as possible after data collection. Data entry should occur each week unless longer time frames are approved by the Project Manager and Network Data Manager. At no point should field notebooks be substituted for data sheets. Data sheets should be designed following the specifications outlined in the Klamath Network Data Management Plan (Mohren 2007).

Prior to starting a new record in the database, all field-generated data will be reviewed for accuracy during and immediately after measurement and data entry. Data also should be checked for completeness and accuracy prior to leaving each site. All data received from a contracting laboratory will be reviewed for accuracy upon receipt by the Project Manager. Data collected using data loggers should be checked immediately after downloading the data. Field-generated data should be reviewed by the field-crew leader, although each field-crew member will be familiarized with expected values for field parameters being measured so that they also can participate effectively in data quality assurance and control.

All data sheets will be bound and stored in a fire-proof, locked cabinet at the end of a sampling day. At the end of a sampling period, upon returning to the Klamath Network office, datasheets will be scanned into a PDF format with a naming convention outlined in the protocol. PDF documents will be stored in the project folder located on the Klamath Network drive. Original data sheets will be stored in a dry, fire-proof container at the Klamath Network Monitoring Program office in Ashland, Oregon.

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

6.4. Data Verification and Validation

Data verification is the process of ensuring that data entered into a database accurately duplicate data recorded in the field. Field crew members should implement the following process to verify data:

1. **Visual review at data entry**— This method should always be used when entering data. In this method, the crew member entering the data verifies each record after input. Records are checked to ensure all parameters have been entered and that the values make sense. If hardcopy data sheets are being used, records entered into the databases are compared to the data on the hardcopy datasheets. Errors or missing values are corrected immediately.
2. **Visual review after data entry—** After the data have been entered, and prior to leaving the site, records should be double-checked to ensure they are complete and accurate. When possible, this should be completed by someone other than the person who entered the data.
3. **Final Review—** After following the processes outlined in number 1 and 2 above, it is the Project Manager's responsibility to review a predetermined subset of records that have been entered into the database and compare them to the original hardcopy forms if available. A timeline should be developed during the project's planning phase to outline the number of records that will be checked and a time frame as to when they will be examined.

While data verification can be completed by someone with little to no knowledge of the data, data validation requires a reviewer to have extensive knowledge on what the data mean and how they were collected. Data validation is the process of reviewing the finalized data to make sure the information presented is logical and accurate. The accuracy of the validation process can vary greatly and is dependent on the reviewer's knowledge, time, and attention to detail. General data validation procedures include:

1. **Data entry application programming—** Filters for illegal data will be used, when possible, to prevent data being entered that exceeds its logical value (e.g., 2m vs. 200m stream depth). It is important to note that not all fields have appropriate domains and it will be the responsibility of the Project Manager to examine these fields for erroneous data.
2. **Outlier detection and review—** An outlier is an unusually extreme value for a variable, given the statistical model being used to analyze the data. It is important to note that not all outliers are a result of data contamination; they may be indicators of important thresholds or extremes in variation of the parameter of interest. Statistical tests such as Grubbs' test, regression mapping, and graphical displays such as scatter plots will be used to examine the data for outliers (Michener et al. 2000). Depending on the analysis methodology, outliers may not need to be removed. A determination will need to be made to define what is considered an "unusually extreme" value indicating data contamination or an environmental aberration that clouds the interpretation of the field measurement. Generally, non-error-associated outliers

should be flagged and retained, allowing those conducting data analysis to make determinations about inclusion or rejection.

3. **Review of what makes sense.** The Crew Leader and Project Manager should be intimately familiar with the types of data being collected, including expected data ranges. The individuals in these roles should review the tabular data to make sure it appears logical. GIS data should be plotted and examined to determine the accuracy of the spatial locations (Sanders 2005).

6.5. Quality Assurance and Control

As we continue to develop the Klamath Network Data Management Program, it will be important to constantly review and update data management procedures for each project. During any project managed or funded by the Klamath Network, we will:

1. Work with the Project Manager and Crew Leader to examine current QA/QC procedures and, if needed, update or change those procedures. A log will be kept to record any major or minor revisions to the data management procedures of a project.
2. Conduct field checks of Klamath Network projects early in the field season to make sure that they are conforming to all standards and protocols.
3. Collect evaluation forms on a seasonal basis from field-crews to determine the need for improvement in data management or training associated with data management. Evaluation forms will be developed on a project-by-project basis.
4. Confirm that data management processes are clear and useful by working with the Project Manager and field-crews to make sure that all are comfortable with all data management processes.

Quality control and assessment procedures, along with a statement assessing the overall quality of data, will be included in the metadata for each project.

6.6. Metadata Procedures

A metadata record will be prepared for the NPSTORET monitoring program database. Creation of a metadata file is an integral part of any project that collects samples that generate data, data files, and/or a database. Metadata consists of information that documents and characterizes information contained within data files and databases. The overall goals of metadata creation are to develop a comprehensive document that (1) explains enough about the project data to ensure they are useable by future personnel and the scientific community, and (2) complies with FGDC and NPS mandates for federal projects. Metadata development begins at the start of every project; as the project develops, so do the metadata. Within the sideboards set by the program and federal requirements, the process of metadata creation will vary depending on goals and objectives, funding, and scope of the project. It is the responsibility of the Data Manager to set forth the metadata requirements and the process used to create the metadata. These requirements will be outlined in the protocols for each monitoring project.

The metadata for a project should be created prior to implementing the field season and will need to be updated at the end of each field season. The Klamath Network utilizes a metadata interview form that describes the various attributes of a dataset. The interview form includes information about the time frame, description, sensitivity, collection location, and purpose of the data, plus various other pieces of information needed to develop the metadata for the dataset. It is the Project Manager's responsibility to complete a new metadata interview form before the start of the first field season and at the end of each additional field season.

In addition to metadata associated with each spatial product and database, the Klamath Network requires metadata to be provided for each photograph used to capture some aspect of a monitoring project (e.g., field-crew, sites, sampling method). Photographs are a valuable tool used for a multitude of objectives including conducting outreach, identifying specimens, displaying habitat conditions, documenting fieldwork, and analyzing data. It is the responsibility of the field crew and the Project Manager to follow the Klamath Network Photograph Guidelines available through the Klamath Network internet or by directly contacting the Network Data Manager. The Project Manager should submit project-related photographs and photograph metadata to the Data Manager at the end of each project.

6.7. Storage

When collecting data electronically in the field, a backup of the database will be made prior to leaving a field site. The backup of the database should be stored to a source that is external of the tablet PC. Once out of the field, data from the tablet PC should be stored in a desktop or laptop computer. Backups should be placed in a separate folder that contains subfolders organized by date.

When returning to the Network office, data should be reviewed by the Project Manager and transferred to the Network Data Manager along with a data certification form. Once submitted to the Data Manager, the data will follow the backup process implemented by Southern Oregon University that includes nightly, weekly, and quarterly backups stored for two months (nightly and weekly backups) or one year (quarterly backups). Backups are originally stored in a Scalar I500 tape library. Once backups are complete, the tapes are moved to a fire-safe room where they are stored for one week prior to being moved to a locking fire safe. The tapes are stored in the fire safe for an additional week and then moved off-site to a storage system maintained by Records Masters of Southern Oregon.

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

6.8. Data Distribution

The Klamath Network utilizes the Network's internet and intranet websites, Southern Oregon University, and the National I&M databases to disseminate information to the parks and the general community. Prior to dissemination, all spatial information must be associated with FGDC-compliant metadata. Documents should be in the proper format as described in the Klamath Network Data Management Plan. It is the responsibility of the Data Manager to work with the Project Manager and park staff to determine the sensitivity of the data prior to posting. Constraints will be placed on sensitive data to prevent or limit distribution to the public.

The Klamath Network will send raw field data from NPSTORET to the WRD on an annual basis for quality assurance and upload into the WRD's copy of STORET and the Environmental Protection Agency's (EPA) STORET National Data Warehouse (Figure 3).

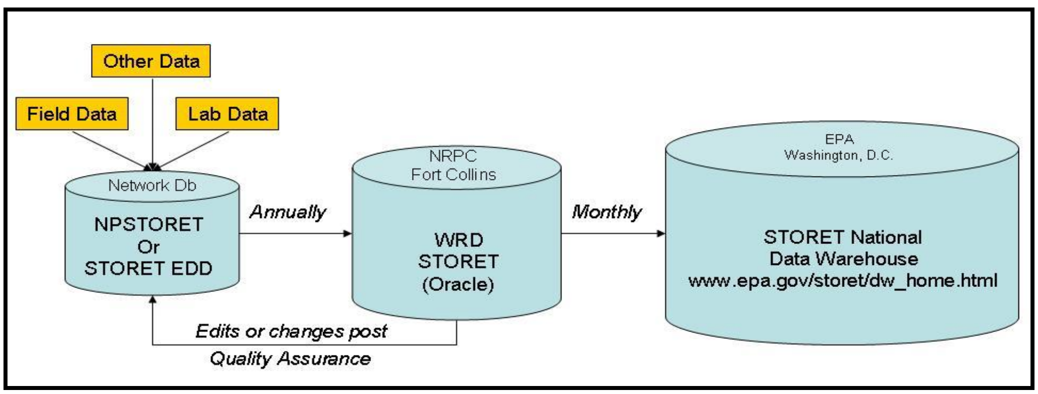

Figure3. Simplified conceptual model of the Natural Resource Challenge vital signs water quality data flow from collection to distribution.

Appendix E. Supplemental Plan for Water Quality and Aquatic Community Monitoring (continued).

Chapter 7: Data Analysis and Reporting

The focus of data analysis will be to: (1) determine the range of natural variation of water quality and biotic community parameters in each freshwater ecosystem being monitored; (2) use knowledge of natural variability to set informed threshold standards for each ecosystem parameter; and (3) identify potential ecosystem change relative to the natural variation and threshold standards of indicator parameters (see Klamath Network Vital Signs Monitoring Plan, Chapter 7).

Multiple types of data description and statistical analyses will be used to analyze water quality and aquatic community data because the fundamental objectives of this integrated monitoring plan are to determine baseline conditions (or status) of monitored ecosystems and potential deviance of baseline conditions beyond natural variation. Some statistical methods are appropriate for summarizing and documenting baseline conditions within and among groups, others are useful for documenting ecosystem trends, and additional methods allow for the description and elucidation of aquatic communities. These methods will be described in detail in SOP 12. An important document to be used as guidance is: Helsel, D. R., and R. M. Hirsch. 2002. Statistical methods in water resources, Chapter A3, Book 4, Hydrologic analysis and interpretation, Techniques of water-resources investigations of the United States Geological Survey, USGS. 510 p.

7.1. Analysis of Status

Summary statistics are useful for identifying and illustrating the characteristics of data, the baseline conditions or status of ecosystems, and for determining how data can be appropriately analyzed. An initial review of collected data helps identify the central tendencies (e.g., sample mean and median), spread (e.g., sample variance and range), and skewness (i.e., sample symmetry or asymmetry) of the data. The review also identifies outliers and provides the information necessary for determining if data need to be transformed prior to analyses. These metrics will be useful for identifying the range and variation of parameters and conditions of ecosystems within and among parks. Graphical analysis of these metrics also can be useful for identifying and visualizing ecosystem status. The analysis of collected data using parametric and non-parametric univariate statistical methods will be useful for identifying any significant differences in parameters that might indicate potential divergence or change in ecosystem status. Finally, multivariate indices of biological and ecological integrity (see Karr and Chu 1999), which are techniques constructed of methods sensitive to biological and ecological conditions, also will be useful for predicting and modeling potential change in ecosystem status (see Hawkins and Carlisle 2001).

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7.2. Analysis of Trend

Trend analysis is primarily concerned with change (or lack of change) of a parameter or parameters of interest through time, although spatial and directional trends may also be investigated (Helsel and Hirsch 2002). There are two basic types of tests that are useful for analyzing trend: (1) the nonparametric Mann-Kendall trend test, and (2) the parametric method of the regression of Y on T (time). In addition to these tests, a useful methodology that can be used with count data, especially counts of organisms, is the ΔN Method developed for estimating trends in amphibian populations (Houlahan et al. 2000; Green 2003). Time series scatter plots and scatter-and-line plots also are useful for expressing and identifying trends.

7.3. Metrics for Aquatic Community Data

A number of metrics and methods exist for the analysis of ecological communities (McCune and Grace 2002). Several basic diversity indices could be used to elucidate aquatic communities including: (1) species richness (total number species present, Margalef Index, Menhinick Index), and (2) species diversity (Simpson's Index, Shannon-Wiener Index, niche breadth). In addition, multimetric and multivariate bioassessment tools are available for assessing the biological integrity of aquatic ecosystems including: (1) use of the ratio of observed (O) taxonomic composition to the expected (E) composition of a community (Hawkins and Carlisle 2001), (2) rapid bioassessment of biological integrity using benthic macroinvertebrates, periphyton, and/or fish (Barbour et al. 1999), and (3) the proportion of sites occupied (PAO) method adopted by the USGS Amphibian Research and Monitoring Initiative (see MacKenzie et al. 2002, 2003).

7.4. Reporting Schedule and Format

The Network Aquatic Ecologist (i.e., Project Manager) will be responsible for compiling and analyzing data for programmatic reports. The Annual Report will be used to document key findings and monitoring activities each season, describe current conditions of the monitored ecosystems, and document changes in the monitoring protocol. The Analysis and Synthesis Reports will involve more detailed analyses across multiple years. The Analysis and Synthesis Report will be used to communicate ecosystem patterns and the results of trend analysis, including baseline ecosystem conditions and determination of any changes to baseline conditions beyond natural variation. This report will initially be completed after the completion of the first cycle of monitoring (i.e., year 4) and, at minimum, every three years thereafter. All reports will be distributed to each park unit, the Network I&M Program Coordinator, and the NPS WRD. Data analysis will be helpful for reviewing and assessing the importance and relevance of the parameters being measured and for revising monitoring program objectives, sampling schedules, and SOPs. Periodic formal peer-reviews of the monitoring program and protocol will be conducted for program quality assurance and continuity. Details regarding reporting schedules, format, and content will be provided in SOP 13.

Project-related reports and analysis and synthesis reports will be published in the NPS Natural Resource Publication Series. Documentation of the NPS publication standards are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm. Reports will be developed using the NPS Natural Resource Publications template, a pre-formatted Microsoft Word template document based on current NPS formatting standards. Scientific journal articles, book chapters, and interpretive and outreach materials should be developed in the format designated by the authority where the material will be published.

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Chapter 8: Administration/Implementation of the Monitoring Program

See Chapter 8 of the Klamath Network Vital Signs Monitoring Plan for complete details concerning the administration and implementation of the integrated freshwater quality and aquatic community monitoring plan.

A brief description of the staffing, and roles and responsibilities of personnel participating in the implementation of the plan is summarized below:

1. The Network Coordinator has overall responsibility for implementing and supervising the Klamath Network Integrated Freshwater Quality and Aquatic Community Monitoring Program, is responsible for the successful completion of all aspects of the program, and directly supervises the Network Aquatic Ecologist and Data Manager.
2. The Network Aquatic Ecologist is responsible for managing the day-to-day activities of the monitoring program; supervising seasonal crew members; providing them with tactical and logistical support during the field season; verifying, validating, and analyzing data; and writing and completing Annual and Analysis and Synthesis Reports.
3. The Network Data Manager is responsible for creating and maintaining the program database and providing guidance to Network monitoring program staff as to the proper use of the database and assisting program staff in the archival of electronic data.
4. The Crew Leader is supervised by the Network Aquatic Ecologist and is responsible for supervising crew members in the field and the successful completion and verification of monitoring program tasks, including but not limited to the collection, storage, and shipment of field samples and the proper entry of data into the monitoring program database. The seasonal Crew Leader also is responsible for the proper calibration, use, and/or maintenance of monitoring program instruments, equipment, and gear. The seasonal Crew Leader will have experience in conducting aquatic fieldwork in relatively remote, isolated locations, at least some minimum experience in supervising peers, and demonstrate the ability to live and work cooperatively with others under often stressful and challenging conditions for extended periods.
5. The Crew Members are supervised by the Crew Leader and will be responsible for successfully completing all monitoring program tasks, including but not limited to the collection, storage, and shipment of field samples; the proper recording of field data on field data sheets; and the proper entry of data into the monitoring program database. The Crew Members will have at least minimum experience in conducting aquatic fieldwork in relatively remote, isolated locations, and demonstrate the ability to live and work cooperatively with others under often stressful and challenging conditions for extended periods.
6. Designated NPS staff at each park will be responsible for sampling core parameters at Judgment and Index sampling sites during off years (see following section for scheduling details).

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Chapter 9: Schedule

9.1. Annual Workload and Field Schedule

Tasks to be accomplished annually include: (1) assessment and sampling of monitoring sites during the summer field season, mid-June through mid-September; (2) data entry and database QA/QC; (3) archiving of field data sheets; (4) data analysis; (5) completion of report summarizing monitoring program activities and data analysis; (6) instrument, equipment, and sampling gear inventory and replacement if needed; and (7) instrument calibration. An Analysis and Synthesis Report will be completed every fourth year that will summarize historical and contemporary program activities and data analysis.

Two 2-person crews will perform assessment and sampling activities at monitoring sites during the summer field season. The crews will visit separate sites and will be responsible for the intensive assessment and sampling of physical habitat characteristics, water chemistry, and biological community parameters. Crew members will work four 10-hour days per week.

The crews will be responsible for:

1. Visiting all judgment, index, and survey sampling sites;
2. Measuring, determining, and recording core parameters and physical habitat characteristics at each site;
3. Collecting and field processing, when required, water chemistry and biological community samples at each site;
4. Transporting water chemistry and biological community samples from the field to an in-park holding facility and maintaining samples according to proper sample handling and holding SOPs;
5. Preparing water chemistry and biological community samples for transport or shipment to contract laboratories for processing;
6. Processing any biological community samples not sent to contract laboratories;
7. Data entry and QA/QC;
8. Sampling instrument and equipment calibration, maintenance, and QA/QC.

9.2. Sampling Rotation for Years in which Ecosystems are Scheduled to be Sampled in each Park

The two crews will rotate among the parks, completing the sampling of monitoring sites in one park before beginning sampling at the next park. The sampling rotation should be the same in subsequent years to assure that monitoring sites in each park are sampled at the same time of each field season. The tentative sampling rotation for the first three years will be:

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1. Year 1 (tentative 2008)
   A. Ashland: Training and Orientation (first week of season; approximately June 16-19)
   B. Redwood NP: wadeable cold-streams 1-30
   C. Oregon Caves NM: Cave Creek 1-3
   D. Crater Lake NP: wadeable cold-streams 1-28
   E. Ashland: sample processing, data entry, instrument calibration (end of season)
2. Year 2 (tentative 2009)
   A. Ashland: Training and Orientation (first week of season; approximately June 15-18)
   B. Whiskeytown NRA: wadeable cold-streams 1-30
   C. Oregon Caves NM: Cave Creek 1-3
   D. Lassen NP: wadeable cold-streams 1-28
   E. Ashland: sample processing, data entry, instrument calibration (end of season)
3. Year 3 (tentative 2010)
   A. Ashland: Training and Orientation (first week of season; approximately June 21-24)
   B. Redwood NP: Freshwater Lagoon 1
   C. Lassen NP: ponds-lakes 1-29
   D. Crater Lake NP: ponds-lakes 1-29
   E. Ashland: sample processing, data entry, instrument calibration (end of season)

9.3. Off Year Sampling of Index and Judgment Sites

Off year sampling refers to the sampling of sites in each park during years when those sites are not scheduled to be visited or sampled by the seasonal crews (e.g., years 2 and 3: wadeable cold-streams at Redwood NP; years 1 and 2: ponds-lakes at Crater Lake NP; see Table 4). Designated NPS staff at each park will be responsible for sampling core parameters at index and judgment sites during off years. Survey sites will not be sampled in off years. The tentative schedule (one complete cycle) will be:

1. Year 2 (tentative 2009)
   A. Redwood NP: wadeable cold-streams, 16 sites
   B. Crater Lake NP: wadeable cold-streams, 14 sites
2. Year 3 (tentative 2010)
   A. Redwood NP: wadeable cold-streams, 16 sites
   B. Crater Lake NP: wadeable cold-streams, 14 sites
   C. Lassen NP: wadeable cold-streams, 14 sites
   D. Oregon Caves NM: cave stream, 3 sites
   E. Whiskeytown NRA: wadeable cold-streams, 15 sites
3. Year 4 (tentative 2011)
   A. Redwood NP: lagoon, 1 site
   B. Crater Lake NP: ponds-lakes, 15 sites
   C. Lassen NP: wadeable cold-streams (14 sites), ponds-lakes (15 sites)

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   D. Whiskeytown NRA: wadeable cold-streams, 15 sites
4. Year 5 (tentative 2012)
   A. Redwood NP: wadeable cold-streams (16 sites), lagoon (1 site)
   B. Crater Lake NP: wadeable cold-streams (14 sites), ponds-lakes (15 sites)
   C. Lassen NP: ponds-lakes (15 sites)
5. Year 6 (tentative 2013)
   A. Redwood NP: wadeable cold-streams, 16 sites
   B. Crater Lake NP: wadeable cold-streams, 14 sites
   C. Lassen NP: wadeable cold-streams, 14 sites
   D. Oregon Caves NM: cave stream, 3 sites
   E. Whiskeytown NRA: wadeable cold-streams, 15 sites

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Chapter 10: Budget

10.1. Startup Costs and Budget Considerations

Start up costs will include the purchase of instruments for the measurement of core parameters and additional supplies not presently part of the Network gear and equipment inventory. Sampling of the Network's wadeable cold-streams and ponds-lakes will be quite labor intensive; 67-71% of the budget in the first three years will be required to support personnel (salaries and benefits) and travel (vehicles, fuel, and per diem) costs. In addition, the water quality and aquatic community monitoring program budget will potentially be impacted in subsequent years by increasing fuel costs, cost-of-living increases for salaries, and potential increases in overhead charges for personnel benefits and administrative fees. The estimated total program costs (in 2007 dollars) for the first three years of the monitoring program are summarized below:

LINE ITEM	YEAR 1	YEAR 2	YEAR 3
SALARY & BENEFITS			
1 GS-11 (Supervision): 2 PP @ $2779/PP	5558	5558	5558
1 GS-7 (Field Crew Leader): 8 PP @ $1621/PP	12968	12968	12968
3 GS-5 (Field Crew) 8 PP @ $1308/PP	31392	31392	31392
SALARY & BENEFITS SUBTOTAL	**49918**	**49918**	**49918**
TRAVEL & SUPPLIES			
2 GSA vehicles (each = $289/mo; $0.165/mi)	7000	7000	7000
Fuel	3000	3000	3000
Per diem[1]	8000	8000	8000
Supplies and equipment[2]	16874	5000	5000
TRAVEL & SUPPLIES SUBTOTAL	**34874**	**23000**	**23000**
ANALYTICAL COSTS			
Water Quality	12139	12889	11741
Aquatic Communities	7625	7625	13865
Off-year Site macroinvertebrates		3750	7750
ANALYTICAL COSTS SUBTOTAL	**19764**	**24264**	**33356**
TOTAL COSTS	**104556**	**97182**	**106274**
Surplus of initial total budgeted	5444	12818	3726

[1] May need to increase the total cost of this budget item due to increased costs
[2] Year 1 costs for this budget item include the purchase of 2 YSI Model 556 meters ($5100 each) and 2 Hach turbidimeters ($837 each)

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10.2. Analytical and Sample Processing Costs (2007 Dollars)

The table below summarizes estimated costs for the processing of water quality and aquatic community samples. These costs may vary relative to potential cost increases in subsequent years and the contract laboratories and/or consultants selected for sample processing.

Core Parameters	Temperature, Specific Conductance Dissolved Oxygen, pH	See instrument costs above
Water Chemistry	Alkalinity, Specific Conductance	$45
	Cations (Na, K, Ca, Mg)	$28
	Anion (Cl)	$25
	Total Nitrogen	$27
	Ammonia	$11
	Nitrate/Nitrite	$11
	Silica	$11
	Total Phosphorus	$17
	Total Suspended Solids	$16
	Dissolved Organic Carbon	$ 8
	Metals (one Whiskeytown NRA stream)	$250
Biological Samples	Chlorophyll (ponds-lakes only)	$30.00
	Zooplankton (ponds-lakes only)	$80.00
	BMI (streams and ponds-lakes)	$125 (ID only); $250 (process + ID)
Fecal Indicator Bacteria		$60.00

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